# ENGINEERING:

## An Illustrated Weekly Journal.

*EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.*

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**Wanted, by Large Seed** Crushers on the Thames, WORKS MANAGER, for preference a Chemical Engineer. Applicant must have thorough allround training and experience. Good and progressive position for competent man. — Address, O 93, Offices of Engineering.

**Wanted, Immediately, by** large firm (2000 hands) in North Midlands, experienced, capable MAN as Assistant Works Manager, to take control of cycle production on large scale. Highest post-war prospects. No one already employed on Government work will be engaged.—Apply, your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and O 193.

**Works Manager Wanted for** small Engineering Works in South of England, employing about 60 hands. General engineering repairs, fitting shop, iron and brass foundry, forge, etc. Must be experienced mechanical engineer, good organiser. Accustomed to estimating and 6 o'clock man. Permanency.—Address, stating full particulars, experience, age, salary, O 184, Offices of Engineering.

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**Acetylene Welders.—Wanted,** at once, for London works, experienced Acetylene Welder. No one already engaged on Government work or residing more than 10 miles away need apply.—Apply, in first instance by letter, giving all information as to experience, wages required, &c., &c., to Z.C. 793, care of Dracons, Leadenhall Street, E.C. 3. O 217

**Wanted, by a Large Iron, Steel** and coal company, a legally trained MAN, to prepare and conduct arbitration cases and investigate matters connected with variations in wage agreements.—Address, with references stating age, experience and salary required, O 205, Offices of Engineering.

**Assistant Engineer required,** preferably one who has had experience in small high-speed engines and fan work. Write, stating experience, age and salary required. No one living more than 10 miles away or on Government work need apply.—Address, O 211, Offices of Engineering.

**Wanted Assistant Chemist** with experience in the analysis of iron, steel, and non-ferrous alloys, for large works in the North of England. No one at present engaged on Government work need apply. Write stating age, experience and wage required to nearest EMPLOYMENT EXCHANGE, quoting No. A 6182. O 146

**Experimentalist Required, to** take charge of small development department in an Electrical Switch-gear Works. Good theoretical knowledge necessary. No person already employed on Government work will be engaged.—Apply, giving full particulars and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 6079. O 94

**Assistant Engineer Required,** by large firm of Internal Combustion Engine Manufacturers. Must have had a good technical and practical education Preference given to one with experience in the design of high compression marine oil engines. No one on Government work need apply. State age, full details of experience, salary required and when at liberty to commence.—Apply, your nearest EMPLOYMENT EXCHANGE, quoting No. A 6161. O 41

**Works Manager Wanted for** a Paint Factory in London, with good all round experience and able to advise as to the laying out of extensions on modern lines.—Address stating experience, age and salary required, to O 257, Office of Engineering.

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**A Large Firm, Engaged in** the tube industry in the Midlands, has a VACANCY for an ASSISTANT MANAGER. The position offers an excellent opening for a young energetic man not afraid of work.—Apply, in first instance, stating age, experience, place of education, and full particulars, O 241, Offices of Engineering.

**A London Firm of** Engineering Contractors have a VACANCY for Assistant ENGINEER. Must have good sound technical education and practical training. Write, giving experience, age and salary wanted. No one on Government work or living more than 10 miles away need apply.—Address, O 212, Offices of Engineering.

**Required, Engineer with** thorough knowledge of South American markets to represent important English house for British machinery.—Write, stating qualifications, age, salary required, &c., "SOUTH AMERICA," care of Streets, 30, Cornhill, E.C. 3. O 236

**Engineer Examiner Wanted** for checking machine parts. Must have served apprenticeship in the trade, able to use vernier and micrometers and understand drawings. Will be attached to drawing office of large works near Woolwich. State age, experience and salary required.—Address, O 141, Offices of Engineering.

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**Wanted, Qualified Electrical** ENGINEER with good mechanical knowledge, for consulting engineer's office chiefly dealing with Iron, Steel, and Mining work. State age, experience, and salary.—Address, O 158, Offices of Engineering.

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**Wanted. — Machine Shop** SUPERINTENDENT in South of England. Must be experienced in modern machine tools and jigs for rapid production of commercial vehicle parts. No person already engaged on Government work will be engaged. Apply, giving experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 6258. O 245

**Assistant Engineer, for Boiler-** house Supervision, REQUIRED at large London Power Station. Good mechanical training essential, with experience of boiler plant and fuel combustion. Inclusive salary £300 per annum.—Address, O 244, Offices of Engineering.

**First-class Draughtsman** REQUIRED, accustomed to Diesel or Semi-Diesel Engines, for large Engineering Works, Manchester district. No one on Government work will be engaged.—Apply, stating age, experience, and salary required, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 6160. O 40

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**Crane Draughtsmen Wanted,** or men used to designing and detailing special structures. State age and salary required. No one already employed on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and O 2.

**Plant Draughtsman Required** for engineering works in Yorkshire. No one already employed on Government work need apply. —Applicants should state full details of experience and wages required to their nearest EMPLOYMENT EXCHANGE, quoting No. A 6155. O 74

**Tool and Plant Draughtsmen** REQUIRED for urgent Aero and Motor work in progressive Midland works. Permanencies for live, interested, quick men with initiative and ability. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning No. 5316. M 610

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**Draughtsmen Wanted, having** had first-class experience in general Engineering. Establishment is controlled and the position is permanent to suitable man. No person already on Government work will be engaged.—Apply, stating full particulars to your nearest EMPLOYMENT EXCHANGE, mentioning A 6142. O 90

**Wanted, Thoroughly Quali-** fied Mechanical DRAUGHTSMAN or Engineer. One having experience in Small Arms work preferred. — Apply by letter, ADMIRAL SLADE, 92, Victoria Street, S.W. 1. O 100

**Draughtsman Wanted, by** Controlled Establishment in West Riding of Yorkshire. One with experience in design of motor vehicles.
Also a good JUNIOR DRAUGHTSMAN.
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Apply in first instance to nearest EMPLOYMENT EXCHANGE, quoting No. 5858, and giving full particulars. M 404

**Draughtsman (Mechanical)** WANTED, by Railway Company in London, with knowledge of Electric Signal Interlocking Preferred. State age and experience. — Address, O 123, Offices of Engineering.

**Draughtsmen Required, Ex-** perienced on medium or heavy Machine Tools, also one accustomed to Jigs, for Controlled works. Permanency to suitable men. No person already on Government work will be engaged.—Apply, stating full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning A 6143. O 91

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**Draughtsman Wanted, for** Engineer's Office in Westminster. Experience in central station piping arrangements preferred.—Write, stating salary and experience, and when free, A., care of Brown's, 39, Tothill Street, Westminster, S.W. 1. O 178

**Draughtsman. — Wanted, an** Experienced DRAUGHTSMAN for a Machine Tool Works specialising in Lathes. Knowledge of jig design a recommendation. Permanent situation for a good man. No one already employed on Government work will be engaged.—Apply, giving full particulars of experience, age, and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and M 300.

**Draughtsmen.—Two Jig and** Tool Draughtsmen or Juniors WANTED. Must have shop experience. Apply, stating age, full particulars of experience and where obtained, also salary required. No person already on Government work need apply.—Apply nearest EMPLOYMENT EXCHANGE, No. A 6214. O 192

**Draughtsman Wanted for** tools and jigs for engineering works in East Midlands. No one on Government work will be engaged.—Apply, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 6224. O 197

**Draughtsman, with Good** aeronautical experience, REQUIRED for aeroplane factory, London district. No person resident more than 10 miles away or already on Government work need apply.—Address, stating age, full particulars of qualifications and salary required, O 208, Offices of Engineering.

**Jig and Tool Draughtsman** REQUIRED, for Aeroplane Factory, London district. Previous experience of aircraft work preferred but not essential. No person resident more than 10 miles away or already on Government work need apply.—Address, stating age, full particulars of qualifications and salary required, to O 206, Offices of Engineering.

**Required, for Aeroplane** factory, London district, MEN accustomed to ordering and setting operations in planning department. No person resident more than 10 miles away, or already on Government work, need apply.—Address, stating age, full particulars of qualifications and salary required, O 207, Offices of Engineering.

**Draughtsman.— Engineering** Draughtsman with good general experience WANTED for a large manufacturing engineering firm, North of Ireland. Permanent position to suitable man. State age, qualifications, particulars of experience and salary required. No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 6243. O 252

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**Government Controlled** Establishment, situated in the Eastern Counties employed on Aircraft Work, &c., have VACANCIES for a number of good DRAUGHTSMEN. Those with Engineering or Aircraft experience preferred. None on Government work need apply.—Write to nearest EMPLOYMENT EXCHANGE, giving full particulars of experience, age and salary required, mentioning this paper and O 180.

**Civil Engineering Draughts-** MAN WANTED for all-round work. Ineligible for general military service.—State age, qualifications, experience and lowest salary required, to BOX 713, Willing's, 125, Strand, W.C. 2. O 221

**Draughtsmen Wanted Im-** mediately, preferably experienced in condensing plant and vacuum pumps. Give full particulars, experience, age, wages and when at liberty. No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE mentioning this Journal and O 251.

**Draughtsman Required, for** large Ironworks and Collieries in the Midlands. Permanent appointment for suitable man. No person already on Government work will be engaged. In reply, state age, previous experience and salary expected.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and O 242.

**Draughtsman, Mechanical,** REQUIRED by Controlled Establishment, one used to Locomotive work preferred. No person already employed on Government work will be engaged.—Apply, stating age, salary required and experience, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 6225. O 209

**Wanted, a really First-class** Mechanical DRAUGHTSMAN (one with knowledge of any kind of furnace work preferred). State age, experience and salary required.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 6223. No person already employed on Government work will be engaged. O 210

**Wanted, Experienced** DRAUGHTSMAN, for large Engineering Works, Manchester district, used to general maintenance work, lay out of plant, buildings, &c., also general repair of machines. No one already on Government work will be engaged. State age, experience and salary required.—Apply, your nearest EMPLOYMENT EXCHANGE, quoting No. A 6226. M 267

**Draughtsman, Mechanical.** Used to machine tool attachments and able to check drawings. Must be accurate and quick in getting work out when required urgently. No one resident more than 10 miles away or at present employed on Government work need apply. State age, experience and salary required enclosing copies of any recent testimonials.—Address, O 235, Offices of Engineering.

**Wanted, Lady Tracer, Ex-** perienced in mechanical engineering work. No person resident more than 10 miles away or already engaged on Government work will be engaged.—Apply, SMELTON-WRIGHT FURNACES, Ltd., 50, Victoria Street, S.W. 1, stating experience and salary required. O 240

**Jig and Tool Draughtsman** urgently REQUIRED for London district, with previous good experience in Press and Auto work. No one engaged on Government work or residing more than 10 miles away need apply.—Address, stating full particulars of experience, age and salary required, O 238, Offices of Engineering.

**Ship Draughtsman, Experi-** enced, REQUIRED for Reinforced Concrete Shipbuilding. No person at present engaged on Government work need apply.—Apply, with full particulars, to your nearest EMPLOYMENT EXCHANGE, quoting O 229 and this Journal.

**Apprentice Scheme Super-** VISOR, for engineering works, Clyde district, with technical training for teaching, suitable discharged R.E. officer, or officer similar qualifications. No one already on Government work need apply.—Apply, your nearest EMPLOYMENT EXCHANGE, mentioning No. A 6208. O 226

**Foundry Foreman Wanted** by large firm in Midlands. Must be energetic, with sound, practical, and theoretical knowledge of Foundry work in all its branches, both Malleable and Grey Iron, more especially the former. Repetition work. Good prospects. No person already on Government work will be engaged.—Apply, with full particulars, salary required, etc., to your nearest EMPLOYMENT EXCHANGE, quoting No. A. 6236. O 161

**Foreman for Tool Room** WANTED near London. Employing 60 to 70 hands, doing high-class interchangeable work. Applicants must have had first-class experience and be accustomed to the rapid production of tools and capable of running a Tool Room on modern lines. No one resident more than 10 miles away, or employed on Government work will be engaged. —Address, stating age, experience, and salary required, O 187, Offices of Engineering.

**Wanted, Working Foremen,** to train and control women engaged on repetition work in reinforced concrete. Good wages for smart men. No person at present engaged on Government work need apply.—Apply, with full particulars, to your nearest EMPLOYMENT EXCHANGE, quoting O 136.

**Wanted Foreman Construc-** tional Ironwork ERECTOR. Apply stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE quoting number A. 6241. No person already engaged on Government work need apply. O 233

## NOTE ON MONEL METAL.

By John Arnott, Metallurgist to Messrs. G. and J. Weir, Limited, Cathcart.

Within the past few years Monel metal has been in considerable use as an engineering material in America, and in a lesser degree in this country; hence, a few remarks regarding its nature and properties may not be out of place in this journal.

The ore from which the metal is produced is mined at Sudbury, Canada. In the smelting no attempt is made to separate the nickel and copper. The term "natural alloy" which has been applied to Monel metal is not strictly correct, but the metals present are in the same proportion as in the original ore. The name was given by the inventor, Mr. Ambrose Monell, president of the International Nickel Company. Monel metal is supplied in two different qualities, one for forging and rolling, the other for casting.

*Composition.*—Undernoted are several analyses of both rolled rod and castings.

| Material. | Nickel. | Copper. | Manganese Iron. | Silicon. |
|---|---|---|---|---|
| Rolled bar, ⅝-in. diam. .. | 66·02 | 30·01 | Total 3·73 | ·13 |
| Rolled bar, 1¼-in. diam... | 66·68 | 29·94 | Total 3·08 | ·10 |
| Rolled bar, 2½-in. diam... | 67·00 | 28·70 | ·87 3·09 | ·13 |
| Draw tube, ⅝-in. diam. .. | 65·70 | 30·28 | Total 3·86 | ·10 |
| Casting .. .. .. | 66·79 | 28·51 | ·22 3·12 | 1·18 |
| Casting .. .. .. | 65·09 | 29·68 | Total 3·68 | 1·29 |
| Casting made in America | 65·76 | 29·10 | Total 3·42 | 1·58 |

It will be noted that the metal for casting contains from 1 to 1·5 per cent. silicon.

The amounts of phosphorus and sulphur present are very small and only traces of aluminium are present.

*Microstructure.*—The structure of Monel metal, as would be expected from its composition, is a solid solution. The rolled metal (Fig. 1) shows sharply-defined crystal grains, usually twinned. The cast material (see Fig. 2) shows only the cored arrangements which is found in such alloys as German silver. Either alcoholic ferric chloride solution or aqueous ammonium persulphate solution may be used for etching.

*Strength of Rolled Materials.*—Undernoted are the results of physical tests on various sizes of rod., &c.

| Material. | Yield Point, Tons per sq. in. | Tensile Strength, Tons per sq. in. | Elongation, per cent. | Reduction, per cent. |
|---|---|---|---|---|
| ⅜-in. rolled rod .. | 20·1 | 39·8 | 47 | 67 |
| ½-in. rolled rod .. | 20·3 | 39·3 | 46 | 70 |
| ⅝-in. rolled rod .. | 22·2 | 42·5 | 46 | 68 |
| 1-in. rolled rod .. | 19·7 | 41·0 | 46 | 62·7 |
| 2-in. rolled rod .. | 23·4 | 41·5 | 40 | 61·5 |
| Draw tube, 1¼-in. diam., 0·1-in. thick (annealed) | 17·2 | 36·7 | 46 | — |

The above and also the high-temperature tests to be mentioned later, were taken on a 50-ton Olsen testing machine fitted with automatic control of the balance weight. The elongations were measured on gauge lengths which were 4 $\sqrt{\text{area}}$. The yield points given were the loads per square inch at which a permanent elongation of $\frac{1}{200}$th of the gauge length was obtained.

*Effect of Annealing.*—The effect of annealing is shown by the following tests from $\frac{13}{16}$-in. diam. rolled rod (turned to ·564-in. on 2½-in. parallel).

| Condition. | Y.P. Tons per sq. in. | T.S. Tons per sq. in. | E. per cent. on 2 in. | R. of A., per cent. | Brinell. |
|---|---|---|---|---|---|
| Normal .. .. | 28·0 | 39·2 | 38·5 | 66·9 | 174 |
| Annealed, ½ hour at 500 deg. C. .. | 27·4 | 39·1 | 37·5 | 67·4 | 174 |
| Annealed, ½ hour at 600 deg. C. .. | 27·1 | 38·7 | 38 | 69·1 | 167 |
| Annealed, ½ hour at 650 deg. C. .. | 26·2 | 38·7 | 38 | 66·9 | 167 |
| Annealed, ½ hour at 700 deg. C. .. | 19·8 | 36·7 | 41 | 68 | 156 |
| Annealed, ½ hour at 800 deg. C. .. | 14·1 | 34·7 | 49 | 69·3 | 143 |
| Quenched at 800 deg. C. .. .. | 14·8 | 34·0 | 49 | 70·2 | 143 |

It will be noted that the yield point and tensile strength are not reduced below 14 tons and 34 tons per square inch respectively, even by annealing at 800 deg. C. The strength of Monel metal is, therefore, largely "natural" and not dependent on work. There does not appear to be the same liability to develop cracks due to internal strain with Monel metal as with rolled brasses.

*Strength at High Temperatures.*—The curves in the diagram (Fig. 3) (which were reduced to small scale by photostat) were plotted from the results of

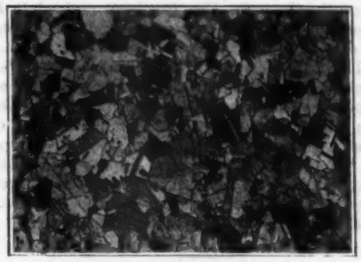


Fig. 1. Rolled Monel Metal; Etched in 5 per Cent. Alcoholic Ferri-Chloride Solution. Magnified 150 Diameters.

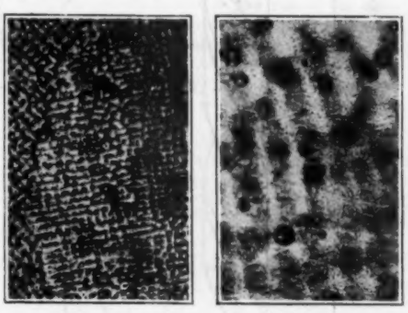


Fig. 2. Cast Monel Metal. Etched in 5 per Cent. Ammonium Persulphate Solution. Magnified 60 Diameters. Magnified 300 Diameters.

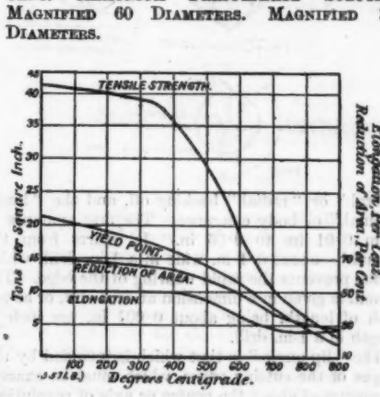



Fig. 3.

tests on 18 bars. The tests were carried out in a small electric furnace designed to suit the testing machine, and the temperatures were taken by a platinum thermo-couple.

| Temperature. | Y.P. | T.S. | E. | R. of A. |
|---|---|---|---|---|
| Normal .. | 21·3 | 41·4 | 51 | 69 |
| 320 deg. C. .. | 17·0 | 38·5 | 48 | 62 |
| 410 deg. C. .. | 15·6 | 33·8 | 49·5 | 63 |
| 500 deg. C. .. | 15·2 | 28·7 | 45 | 56 |
| 630 deg. C. .. | 10·4 | 16·2 | 33 | — |
| 700 deg. C. .. | 7·9 | 10·3 | 27 | 36 |
| 905 deg. C. .. | 1·6 | 2·8 | 27 | 28 |

The yield points are given with some reserve as direct measurement from the bar itself was not possible, and it was, therefore, necessary to observe them on the grips. They are, however, included as they help to give an idea of the behaviour of the metal at increased temperatures.

Monel metal has been largely used because of the strength it possesses at high temperatures. The following figures show Monel metal, compared with rolled naval brass and manganese brass:—

| Temperature. | Monel Metal. T.S. Tons per sq. in. | Naval Brass. T.S. Tons per sq. in. | Manganese Brass. T.S. Tons per sq. in. |
|---|---|---|---|
| Normal .. | 41·4 | 26·0 | 29·0 |
| 295 deg. C. .. | 39·1 | 18·3 | 14·5 |
| 340 deg. C. .. | 38·2 | 13·5 | 9·5 |
| 410 deg. C. .. | 33·8 | 5·4 | 4·4 |
| 500 deg.C. .. | 28·7 | Nil. | Nil. |

*Use.*—Rolled Monel metal has found many applications for valves, pump rods, &c. In one pump working with 300 lb. steam pressure, a rod has been in service for seven years, during which time it has been ground only once. Manganese brass rods working under the same conditions require grinding at least once a year.

The casting of Monel metal presents considerable difficulty. The melting point is high (about 1,360 deg. C.) and the shrinkage large. Experimental work on castings has been retarded since the outbreak of war, owing to difficulty in obtaining material. Many of the castings made have proved very successful in pump practice, notably in dealing with impure water. One such case may be cited. In a certain paper-mill gunmetal and manganese brass valves did not last three months; cast-iron about six months. Monel metal valves were in good condition after two and a half years' service.

## TWIST DRILLS.

The indebtedness of engineers to the University of Illinois, Urbana, U.S.A., has certainly been increased by the extensive experiments on the operation of twist drills lately carried out at that Institution. We have now before us a bulky bulletin* of 144 pages, which forms the latest record of researches made to ascertain the conditions that govern the operation of twist drills. It carries the subject farther than previous investigators have done, and it throws light on some matters that have not been so closely studied by previous experimenters. It is an immense record of patient work, and should be read by those who desire to keep in the forefront of drilling practice. The researches embrace questions of tool angles, of speeds and feeds, and their results in variations in torque = lb.-ft., and in thrust = lb.

Though the twist drill has been in use for more than fifty years it can hardly be said to have been studied seriously before the present century. Most of the investigations made have been undertaken in the United States. The older American firms who have manufactured twist drills for many years past—the Morse Company leading—have done a great deal of experimental work with a view to ascertain the best shapes, speeds and feeds for these drills. The task is not so simple as it may appear to be. No uniformity in results has been achieved, neither does it yet seem possible, unless all the variables that enter into the solution of the many-sided problem might be standardised. One of the most potent of these concerns the construction of the machines, including the kind of bearing used, whether ball-thrusts or plain designs. The grade, or harshness of a steel or cast-iron may halve, or double drill performance. The nature and volume of the lubricant, or the cooling medium used may exercise equally large influences. The mass of metal in which the drill is working is a controlling factor, allied in a sense to that of lubrication, since a large mass will carry away the heat generated more rapidly than a thin body will do. Details of manufacture affect the durability of drills. The hardening and the grinding are important details. Uniformity of texture, homogeneity, exact temper are essentials, freedom from curvature and distortion, fine limits in dimensions, accuracy in the clearances imparted to the shank, these favour the performances of drills. These facts explain, too,

* "An Investigation of Twist Drills," by Bruce W. Benedict and W. Penn Lukens. Bulletin No. 103. Engineering Experiment Station. Published by the University of Illinois, Urbana. European Agent, Chapman and Hall, Limited, London. [Price 60 cents.]

why it is better to purchase from firms of repute than that firms should embark on the manufacture of drills for their private use. That was easily done in the old days when the flat drills were made and tempered by the tool smith, but it is not desirable so to deal with the high-grade tools of the present.

The experiments recorded in this bulletin were restricted to 1-in. drills of high-speed steel, working in soft cast-iron. In explanation of this limitation of tests it is stated that the investigations were essentially preliminary to a more extended series. Standard drills by various makers were used, and other drills were made to order in a large range of helix angles that are never used in the standard tools, solely for the purpose of test.

A twist drill is not so simple a tool as it seems to be at first sight. In making it a subject of study, several details that are contributory to its efficiency have to be remembered. A sketch will be helpful to a rapid understanding of the remarks to follow, by fixing the meaning of terms which are not always applied with precision. Since a twist drill is as truly a cutting tool as a lathe or planer tool is, its cutting angles and clearances are as essential to efficiency as those of the lathe tools are. They do not correspond, but only approximate. The various angles in standard drills by various manufacturers differ, though not very materially. For the purpose of this investigation a number of standard drills was measured, and the results recorded are shown in the following table:—

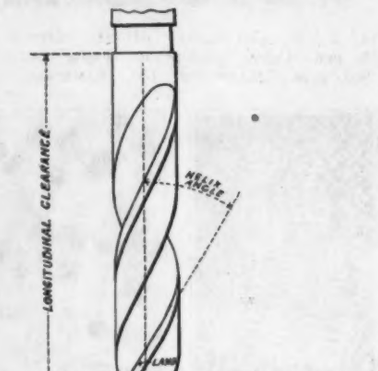
| Manufacturer. | Type. | Clearance Deg. | Point —Deg. | Helix Angle. —Deg. |
|---|---|---|---|---|
| Detroit Twist Drill Company .. .. | Milled | 13½ | 60 | 32 to 27 |
| Detroit Twist Drill Company .. .. | Milled | 7 | 61 | 25 to 20 |
| Union Twist Drill Company .. .. | Milled | 4½ | 58 | 22 |
| Morse Twist Drill Company .. .. | Milled | 2 | 58 | 26 |
| Celfor Twist Drill Company .. .. | Flat-twist | 6 | 63 | 32 |
| Whitman and Barnes | Flat-twist | 5 | 59½ | 29 to 26 |
| Pratt and Whitney .. | Flat-twist | 5 | 59½ | 30 to 25 |
| Lincoln Williams .. | Flat-twist | 6 | 59 | 30 |
| Lincoln Williams .. | Milled | 5 | 58 | 26 to 21 |
| Union Twist Drill Company .. .. | Milled | 5 | 60 | 24 |
| New Process .. .. | Milled | 4 | 59½ | 22 |
| Whitman and Barnes | Milled | 6 | 59 | 26 |

Drill angles are shown in the figure. We take the helix angle first because that determines the incisive character of the tool. It is the angle of spiral of the flutes. It corresponds with the top rake of the lathe turning tool; 26 deg. appears to be the average angle adopted. The pitch of the helix corresponds approximately with one turn in a length of six diameters of the drill. Common drills have two flutes, some used for corrective work have three, or four. These will finish more accurately than the two-flute design, and approach the reamer group in this respect. The helix angle is constant in common drills. In the increase-twist form originated by the Morse Company the angle is lessened from the point towards the shank in the various proportions given in the last column of the table above. The object sought is that of favouring the escape of the chips by increasing the space at the tang, which would otherwise be lessened by the greater thickness which is imparted to the web there to enable it the better to resist torsional stresses. The disadvantage is that the cutting angle—"top-rake"—becomes less keen by several degrees when the drill is ground back.

With regard to the assumed parallel that exists between the cutting angles of the lathe and planer tools and those of the twist drills, the authors point out that this cannot be relied on for practical application, since the entire operation of the twist drill is different from that of the lathe tool. "No part of the cutting edge has the same speed as any other part. The drill point is only kept cool as the heat is conducted away by the metal being cut. The support given the drill by the metal upon which it is operating, the varying clearance of the cutting edge, and the difficulty of cooling, and of chip disposal cause drill design to present its own peculiar problems, although it is possible that much may be learned from the lathe tool design."

In a twist drill the helix angle is that measured at the periphery, changing to zero at the centre, and giving a very small angle of 3 deg. or 4 deg. only, at the edge of the "chisel point." So that the average helix angle at the middle of the lip lies between the two extremes. Following this to its logical conclusion a drill for cast-iron should have an angle of about 28 deg. at its periphery for cast-iron, and one for steel an angle of 40 deg. Instead, most drills have angles of 26 deg. at the periphery. A good many years ago drills were manufactured with angles differing to suit iron, steel, and brass. Recently the same idea has been revived in high-speed drills, with a helix angle of from 30 deg. to 35 deg. at the periphery.

The "lip clearance" or "clearance angle"—the backing off is that imparted from the cutting edges backwards, corresponding with the front rake of the lathe tool. It is 5 deg. or 6 deg., but often more. It should be preserved from the periphery to the point, but in a drill improperly ground it may diminish to zero at the point. To prevent the drill from rubbing excessively in deep holes, two clearances are provided permanently, the "peripheral" or "radial" backing off, and the "longitudinal," or body clearance. The first amounts to from 0·01 in. to 0·05 in. It starts from the "land"—about 0·1 in. wide in a 1-in. drill, which width prevents the rapid wearing of the edge. The second is given in a dimension at each end, or as per inch of length, being about 0·001 in. per inch of length in a 1-in. drill.




The "lip angle" is that which is included by the slopes of the cutting edges, which must be exactly symmetrical about the centre or axis of revolution, and each edge of precisely the same length, for if they are not, the task of cutting will not be shared equally by the two, and if of unequal lengths the hole will be larger than its drill. This angle is commonly standardised at 118 deg. "included angle" or 59 deg. the angle of each lip with the axis, which gives straight lips on the standard flute.

If the analogy that exists between the drills and the lathe and planer tools is pursued to its logical conclusions, then the lip angle should be varied, being made more acute for the softer materials, and more obtuse for the harder kinds. This, though desirable, would, like altering helix angles, greatly increase the numbers of drills stocked. This alteration of angles would also influence the performances of the drills, and the character of the chips. To increase the lip angle has the effect of shortening the length of the lips, so that there is less cutting edge available for the removal of metal. The angle of the chisel point also becomes more obtuse, and its scraping action is intensified.

In experiments with the standard 118-deg. included lip, or point angle, drills showed progressively better with increasing helix angles until the helix angle of 32 deg. was reached, and then they became progressively worse with further increases. But with 138 deg. included-point angle, the drills showed better, until 35 deg. of helix angle was reached, and then worse with further increases. For drilling holes at depths exceeding 3 in., a drill with a large helix angle gives the best results. Such holes should be drilled at as high a speed as possible, for then the screwing action of the flutes removes the chips more nearly completely. With regard to the increase-twist design, the conclusion arrived at was that this is apparently of small value, while the lessening of the cutting angle as the drill becomes worn back makes more demands on the power required to drive it, and lessens its endurance.

Tests were made on the effect of changes in the included-point angle, ranging from 88 deg. to 148 deg. The thrust was found to be greatest with the large angles, and least with the small ones. The general tendency is for torque to increase as the angle becomes smaller. With a standard 118-deg. point angle, and a 7-deg. lip clearance, a few holes dulled the drill but slightly. With the same clearance, and 138 deg. included-point angle four holes burned the drills so that they could not be advanced more than a fraction of an inch in depth. But with a 7-deg. clearance, and a 98-deg. point angle no drill was perceptibly dulled by any hole, though there was a tendency to chip the lip edges, and the chisel point, because of the insufficient backing of metal.

Changes in point angle affect the contour of the lips. The standard 59 deg. = 118 deg. included angle, gives, as mentioned, straight lips viewed from the end. There is a prejudice in favour of straight lips, but they are not essential. Smaller angles give convex cutting edges, larger angles edges slightly concave. A few degrees of alteration in angles make little difference in results. One drill which was almost equally efficient for all point angles had a concave cutting edge. The angle may be made more obtuse with advantage for cutting hard materials, and the crystalline brass where the standard angle drill has a tendency to dig in, and for which therefore straight-fluted drills are preferred.

Some photographs, given in the bulletin, of the chips removed by drills of different angles, are instructive. The drills with very low helix angles all show badly-comminuted chips, those with the highest angles, with thinner cutting edges produce long continuous curling shavings. Low-point angles in combination with variable helix angles yield broken chips. The standard 118-deg. point angle did not show so clean a record in chip formation as a point angle of 138 deg. did. The drills with convex edges rolled off tightly-coiled chips, which broke easily. Those with concave edges produced long freely-coiled shavings. The standard straight-edged lips turned off coiled chips which nested more closely than those from the concave edges did. And the drills which produced the longest coils consumed the least power. The inference was that drills with concave edges, and with the largest chip spaces appeared to give good results under all conditions of work, and of point grinding.

Variations in the angle of lip clearance are controlled by the grinder. Their importance is fully recognised, not because the angle at the periphery matters so much, beyond the fact that an excessive clearance there has the effect of weakening the cutting edge; but by reason of the influence which the angle at the centre has upon that of the narrow "chisel edge." In badly-ground drills the angle may be zero, while it should not be less than the clearance angle at the periphery. A drill ground without clearance at the centre will show the chisel edge straight across, but it should lie at an angle of 135 deg. with the straight part of the flute (see the figure). It may range from 130 deg. to 140 deg., the latter being better for heavy feeds. If it exceeds this, the chisel edge becomes weakened.

With regard to the lip clearance (see the figure) experiments were made on drills having amounts ranging from 2 deg. to 15 deg. Endurance lessens with increase in angle; the best performances lay between 2 deg. and 7 deg., beyond which the edges became dulled too rapidly. The conclusion was

justified that 2 deg. at the periphery is ample for all ordinary work, provided the chisel edge angle is 130 deg. or more. The reason why large clearance angles are sent out by the makers is to allow for poor grinding, with probable thickening of the cutting angle. Some tests of endurance for clearance angle gave the following results. For a 4-deg. clearance, the total distance drilled was 14½ in., for a 6-deg. clearance, 25½ in., for a 9-deg. clearance, 18¾ in., for a 12-deg. clearance 17½ in. Other endurance tests in which the grades of hardness of material influence results were these: With 15 deg. of lip clearance, and 124 deg. included point angle, a drill went through about 240 in. of cast-iron with no perceptible increase in dulness. Then on an unusually hard block it broke down after drilling 10 in. With a 4½-deg. clearance, and 112 deg. point angle the drill went through 240 in. of soft cast-iron, through 40 in. of the hard block, and then continued until it had drilled through about 3,000 in. of iron. At 2,400 in. the power required had increased by about 25 per cent., at 3,000 in. by about 35 per cent. With a 12-deg. clearance, and 118 deg. point angle the drill went through 1,400 in. of iron before the power increased by 25 per cent. The results favour the combination of a small clearance angle, with a point angle rather less than the standard.

In experiments with different kinds of drills—forged, solid-milled and twisted—a general similarity was noted in that, following initial drilling, the tool "settles to a cutting edge," and does its most effective work after the initial sharpness is worn off. A drill would often run through from 500 in. to 800 in. of cast-iron with no variation in the average power curve after the first gradual dulling had taken place. Another fact noted was that of the effect of drilling through the skin in cast-iron. The thrust, which at the first rose almost instantaneously to over 1,000 lb., dropped to about 700 lb. before the drill showed perceptible penetration.

A remarkable revelation is, that the endurance of a drill may be increased by from 300 per cent. to 1,000 per cent. by rounding the sharp corners at the periphery. The probable explanation offered is that the rounding of the corners renders them immune to burning, so that dullness begins at the chisel point and gradually extends outward along the cutting lips. The tests were made on an ordinary drill, and on one with rounded corners, both run at a speed of 575 r.p.m., and a feed of 0·041 in. per revolution, in cast-iron. On the basis of the number of inches drilled for a given increase in torque, an endurance ratio of about four to one in favour of the rounded corners is shown in one case, and of about eight in the other. Other tests were run in blocks of varying degrees of hardness which showed a ratio in favour of the rounded corners of about ten to one in the harder materials, and of three or four to one in the softer. This fact is in harmony with a similar one which occurs in lathe and planer tools. With hardly an exception these have slightly rounded corners. The endurance is increased, since keen corners will chip off.

The effect of the "chisel edge" in increasing torque is negligible, but it increases thrust. This may vary from 25 per cent. and less, to 50 per cent. of the total thrust. To thin the point to half its normal thickness produced a diminution in thrust of about 13 per cent. Experiments were made to determine the value of drilling pilot holes slightly larger than the thickness of the web of the drill, to be enlarged at a second drilling. This has the effect of reducing the thrust of the larger hole by from 60 per cent. to 70 per cent. Such saving is discounted by the fact that holes must generally be drilled at one operation, to be finished with the reamer. Moreover, other experiments demonstrated that the power to be saved by the use of a properly ground drill over that of one poorly ground may be greater than the saving effected by first drilling pilot holes.

With regard to the influence of speeds and feeds on the torque, and on the thrust in soft cast-iron, the variation of torque with feed—equivalent to section of cut—is so nearly direct that it may for practical purposes be so considered. With correct angles, the thrust should increase directly with the feed per revolution. In soft cast-iron the torque decreases as the speed increases, though there is little advantage in running a 1-in. drill faster than 350 r.p.m. Thrust lessens as speed increases for corresponding rates of feed, and may amount to 15 per cent. But the advantage has its limits. So far as power consumption is concerned the best way to remove metal is to use as high a speed and as heavy a feed as the drill will stand. The power difference in some tests was as high as 100 per cent. for the lower rates of feed. In some tests the drills were driven at a constant speed with eight variations of feed, and the power used at the drill point varied almost in direct ratio with the feed per revolution.

Tests were carried out to ascertain the comparative endurance of drills in which the flutes are milled in the solid bar, those in which they are produced by forging, and the flat twisted drills. The last is a design which has been revived to economise the use of high-speed steel. These drilled to the greatest depth with the least expenditure of power, the forged drills came next in efficiency, the milled kind were less so. It appears that forging processes may be regulated to give a harder and tougher product, independently of the chemical composition of the steel.

The authors emphasise the fact of variations in the endurance of drills even in the case of the same tool, because they are found to vary in character from point to tang through uneven tempering or variation in the metal. As shown by the Shore scleroscope they have varied by from two to ten points in hardness, being generally softer towards the tang.

A section is devoted to drill grinding machines. Another on lubrication gives a list of those in common use for different materials. Methods of testing occupy another section. The instruments used in measuring torque and thrust are illustrated and described. The book is fully illustrated with 59 Figs., a large proportion consisting of plotted diagrams.

## REINFORCED CONCRETE RESERVOIRS, MONTEVIDEO.

THE City of Montevideo, capital of the Republic of Uruguay, is situated at the northern side of the entrance to the River Plate, and is a port of call of most steamers trading with the numerous ports on that river and its tributaries. The foundation of the city dates from 1726, and it gradually increased in importance until in 1828, when it was made the capital of the Republic, and the chief port of commerce. In 1908 the population was estimated to be 313,000.

The water supply during the period from its foundation until the concession for the water works was granted consisted in the storage of the rain water which fell on the roofs of the houses and also surface wells, a system which was universal in the early days of the South American Republics. In the year 1879 the Montevideo Waterworks Company, Limited, was founded to take over a concession granted by the Government of Uruguay for the construction of the necessary works for supplying the city with water derived from the Santa Lucia River, which flows into the River Plate further west.

The point on that river at which the water is taken is at a distance of 34 miles from the city, and after being treated with aluminoferric salt, as it is highly charged with very finely-divided alluvial matter, the water is thoroughly filtered and pumped through a steel main 30 in. in diameter and a 24-in. cast-iron main to the service reservoirs situated, at a distance of 12 miles, on a rocky eminence at Las Piedras, the elevation of which is about 300 ft. above the city. The new reservoirs which have recently been completed at this place form the subject of the following description and the illustrations which appear on Plates XXXVI, XXXVII, XXXVIII and XXXIX and on pages 454 and 455.

The growth of the City of Montevideo has been very rapid since it was supplied with pure water by the company, and especially during the last ten years, owing to the development of the Republic of Uruguay, it being the chief port for the export of its products and import of its necessities.

The total volume of water delivered to the city per annum during the past ten years is as follows:—

| | Gallons. |
|---|---|
| 1907 ... ... ... ... | 790,722,680 |
| 1908 ... ... ... ... | 822,349,000 |
| 1909 ... ... ... ... | 918,295,400 |
| 1910 ... ... ... ... | 950,847,700 |
| 1911 ... ... ... ... | 1,031,122,180 |
| 1912 ... ... ... ... | 1,169,950,760 |
| 1913 ... ... ... ... | 1,306,221,621 |
| 1914 ... ... ... ... | 1,280,940,100 |
| 1915 ... ... ... ... | 1,294,324,240 |
| 1916 ... ... ... ... | 1,483,609,820 |
| 1917 ... ... ... ... | 1,583,092,981 |

Up to the present, however, only a portion of the city is supplied with water by the company. As the quantity of water consumed increased it was necessary to add to the capacity for storage in the service reservoirs so that in the event of any emergency there may be ample reserve for the supply of the city. It was, therefore, decided by the company in the summer of 1914 to construct additional service reservoirs, and the Hon. R. C. Parsons, M.A., M.Inst.C.E., was consulted both as to the amount of the additional storage required, and also as to the principle of construction most suitable to the requirements.

It was eventually agreed that two reservoirs, each of a capacity of 6,500,000 gallons or a total capacity of 13,000,000 gallons, should be constructed, that both reservoirs should be entirely roofed over, and that reinforced concrete should be adopted. These additional reservoirs practically double the storage capacity of water for the use of the city.

It was further decided that the top water level of one reservoir should exceed that of the other by 1·5 m. and that the floor levels of both should, on an average, be the same, a slight inclination being given to each for cleansing purposes. The dimensions of the shallower reservoir, known as No. 4, are 64 m. by 64 m. by 17·27 m. depth to top water level, and those of the deeper, known as No. 5, are 64 m. by 64 m. by 18·77 m. to top water level, these dimensions corresponding to a total contents of 13,000,000 gallons.

The formation on which the reservoirs are founded is granite which has suffered considerable disintegration on the surface, and in places is intermixed with hard, but softer, material and is also intersected with fissures. When the site was cleared of superincumbent material, and the rock excavated from the higher points, it was found that the surface throughout the area to be occupied by the reservoirs was of fairly equal hardness with the exception of the fissures, which had to be carefully bridged over and any soft places filled in with concrete.

Figs. 1 to 4, on page 454, show sections and a general plan of the reservoirs, while Figs. 6 to 25 on Plates XXXVI to XXXVIII, show to a larger scale various details to which reference will be made in due course. The two reservoirs are separated from each other by a dividing wall designed of the required strength to withstand the water pressure on either side when one reservoir is full and the other empty.

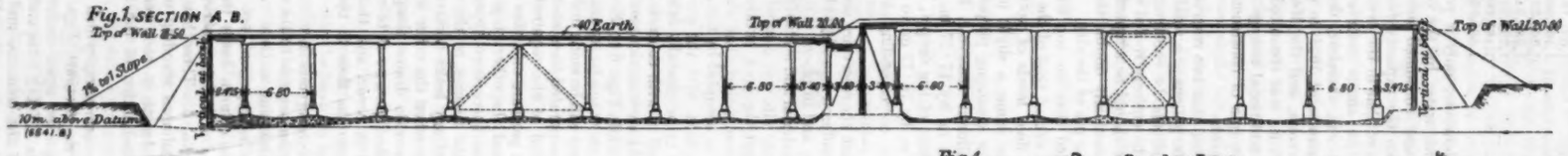
As it was found that there were appearances of springs issuing from the fissures in the rock, and further, in the event of any leaks occurring in the floor of either reservoir when the other was empty, it was necessary to provide drains along the toes of the footings under the floors, so as to relieve any water pressure should it occur, and thus prevent any damage resulting to the floor or the walls of the empty reservoir.

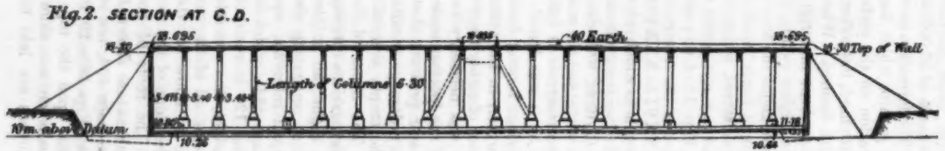
The floors of both reservoirs are made with corrugations running from one side to the other with a slight fall to the cleansing outlets. Along the lines separating these corrugations are placed, at equal intervals, square column bases (see Fig. 5, page 454), which number 162 in reservoir No. 4, and 126 in reservoir No. 5. These bases vary in height, the concrete columns standing upon them being all of the same length in each reservoir, so as to allow for the inclination of the floors and the slope of the roofs.

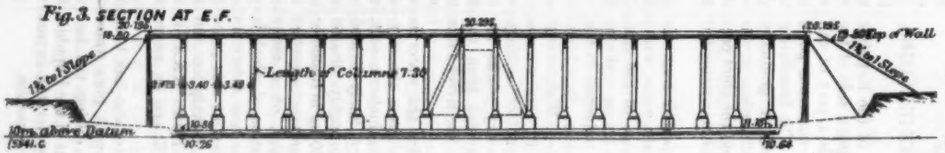
The roofs of both reservoirs, which have the inclination shown in the sections, Figs. 2 and 3, on page 454, are supported upon concrete girders (see Figs. 26 to 29, Plate XXXIX), the ends of which rest upon the tops of the columns, and upon the walls on two sides of the reservoir. Upon these girders are laid the roofs (see Figs. 30 and 31,

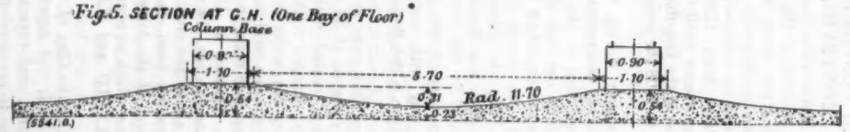
# REINFORCED CONCRETE RESERVOIRS AT MONTEVIDEO.

THE HON. R. C. PARSONS, M.A., M. INST. C. E., ENGINEER, LONDON.



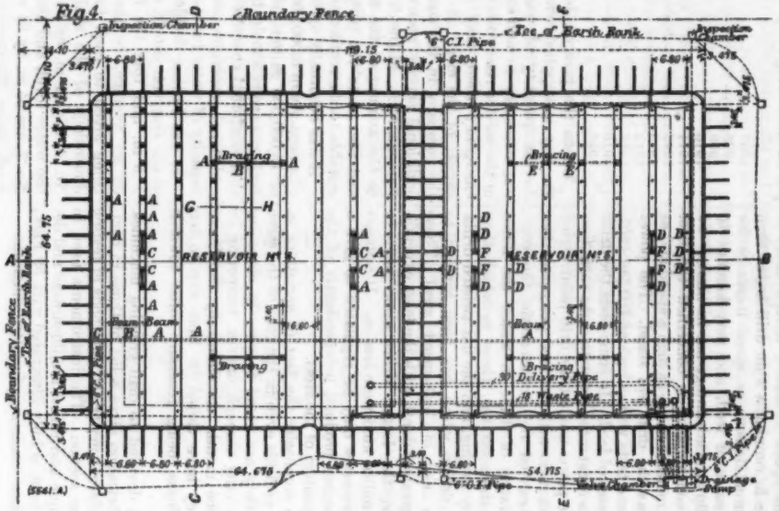




Plate XXXIX), which are continuous all over and extend to the outer line of the walls, where they are formed into continuous girders all round the reservoirs resting on sliding expansion plates placed on top of the walls at intervals of 3·40 m.

As a creep might occur in these roofs relative to the walls a device which Mr. Parsons adopted in connection with the great service reservoir in Buenos Aires, described in a paper published in the Minutes of Proceedings of the Institution of Civil Engineers, vol. cxxiv, was adopted here, viz., that of introducing lattice ties between four sets of columns as shown in Figs. 32 to 35, Plate XXXIX, details being given in Figs. 36 to 41, page 455. These ties at their lower ends have the bars which reinforce them securely attached to the bases, which are firmly built into the floor, and, further, the bases of each pair are joined together by a low reinforced wall. Each set of these lattice ties is capable of resisting any forces which tend to displace the roof horizontally and thus ensure its remaining in its proper position.

The walls surrounding the reservoirs, together with the buttresses which support them, are designed to have an ample margin of strength as no bar is assumed to be stressed to more than 13,800 lb. per square inch, and the compressive strain on the concrete is designed not to exceed 650 lb. per square inch. Further, due precaution was observed that no unnecessary weight of steel or thickness of concrete should occur either in the walls, buttresses or roof.

In Montevideo considerable, and at times rapid, changes of temperature are experienced, consequently every precaution was taken to avoid cracks occurring due to uneven expansion and contraction. In all cases care was taken to avoid any sharp corner or sudden change of section, and especially the outer corners of the reservoirs were designed circular so as to obviate any danger of cracks appearing at these points.

The method adopted for the reinforcement of these corners is shown in Figs. 19 to 22, on Plate XXXVIII. It was also considered necessary to take special precautions against the possibility of cracks taking place at the junctions of the dividing wall between the two reservoirs and the side walls. By reference to the plan, Fig. 4, it will be seen that in each of the side walls to which the dividing wall is attached are constructed special bow bays which allow of sufficient expansion and contraction so as to avoid cross strains arising in the dividing wall. As these bow bays were constructed after the concrete in the walls on either side of them had set, they provided an additional element of security against the formation of cracks. In Figs. 23 to 25, on Plate XXXVIII, are shown the details of the reinforcement of these bow bays, while in Figs. 6 to 10, Plate XXXVI, is shown the principle adopted for the reinforcement of the outer walls, buttresses and footings, and in Figs. 11 to 18, on Plate XXXVII, those of the dividing wall. In Fig. 42, page 455, is shown the reinforcement of the columns, and in Figs. 26 to 29, Plate XXXIX, that of the girders resting upon the tops of the columns, while that of the roofs is shown in Figs. 30 and 31 already referred to. The diameters of the bars for the reinforcements, which were designed to be of mild steel of a tensile strength of 28 tons to 32 tons per square inch, ranged from 1⅛ in., the largest, down to ¼ in., the smallest.

The water reaching the reservoirs from the pumping station is admitted through two mains near the bottom of No. 4, one of which supplies that reservoir and the other is carried through it to No. 5 by passing through the dividing wall, as indicated in the plan, Fig. 4, and shown in greater detail in Fig. 43, page 455. The method adopted for jointing each pipe passing through the wall was by making a smooth hole in the wall of the same diameter as that of the pipes, and also smooth faces on either side of the wall, Fig. 43, page 455. The necessary bolts were built into the wall for drawing up the flanges of the pipes against the faces of the wall and by means of jointing rings an absolutely secure joint is made. This method was adopted, as it was found successful in connection with a service reservoir designed and constructed by Mr. Parsons for Rosario Waterworks in the Argentine Republic. In order to ensure the proper circulation of the water within the reservoirs after it is admitted, suitable deflecting walls are provided.

As it was important that the top water level should be as near as possible to the top of the walls in each reservoir, so as to take full advantage of their capacity, and yet that there should be no danger of either overflowing, specially-designed overflows were adopted, shown in Fig. 43, these preventing the surface of the water rising more than 50 mm. above the overflow, although the full quantity delivered by the pumping engines may be admitted into the reservoirs.

In preparing the designs, although it was essential to protect the walls by means of a substantial backing of earth, against the intense heat of the sun which is experienced at Montevideo, it was considered advisable not to assume that this backing contributed any support to the walls against the overturning moment exerted by the water, while further, to resist the overturning moment of the

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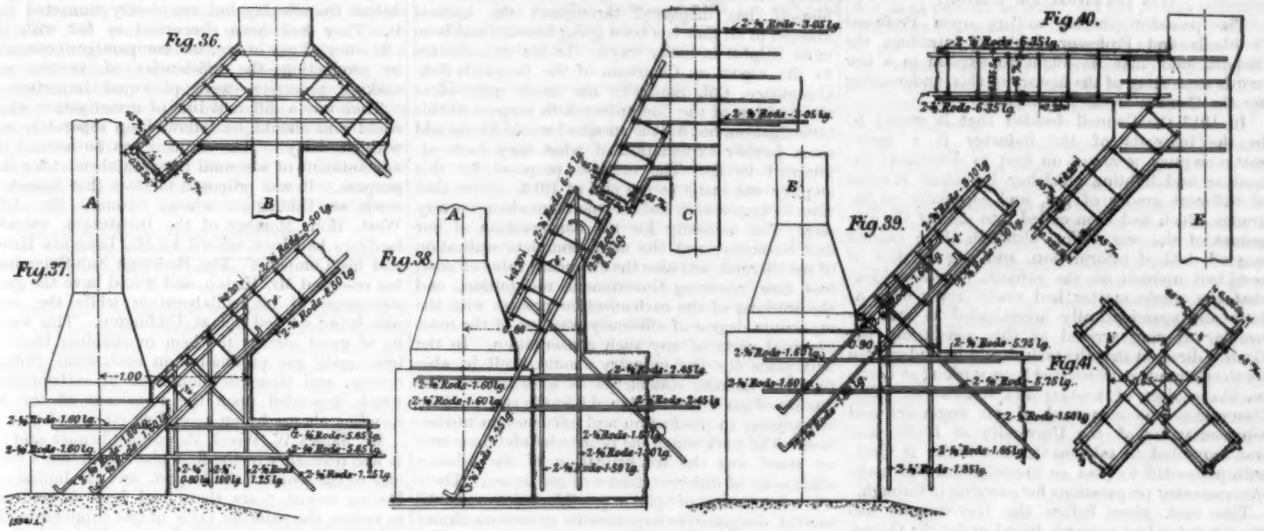


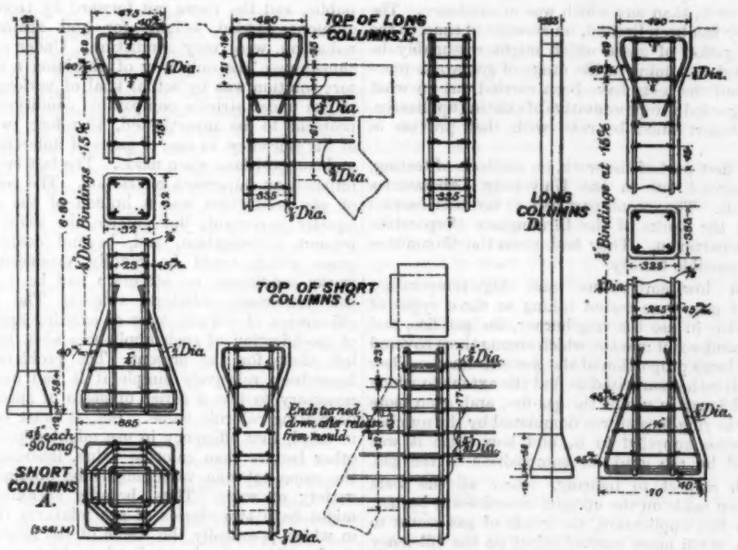




FIG. 42. REINFORCEMENT OF COLUMNS.

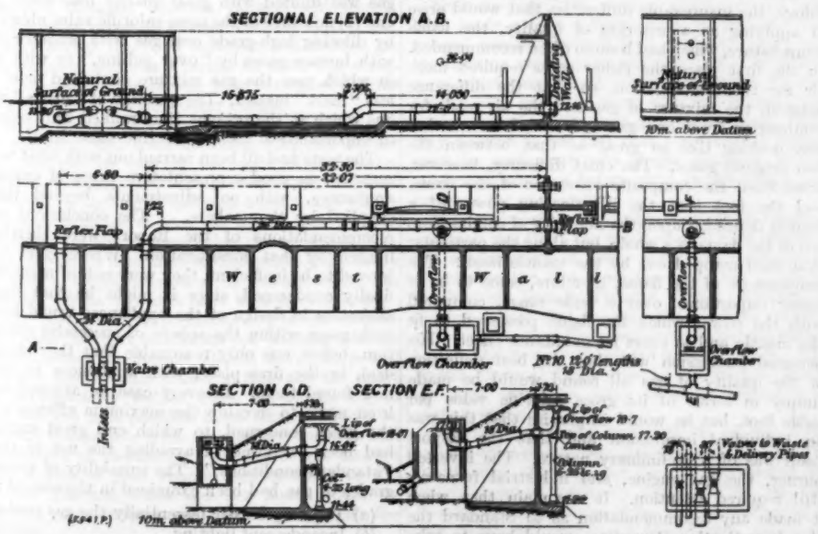



FIG. 43. ARRANGEMENT OF INLET AND OVERFLOW PIPES AND CONNECTIONS.

earth when the reservoirs are empty a "toe" is provided inside, as shown in Figs. 6 and 7, Plate XXXVI.

The roofs are also covered with earth to a depth of 1½ ft., which is found to be sufficient to protect them from the action of the sun. This covering is intersected with surface drains filled with broken stone which connect with iron pipes which carry the water falling upon the area through the roof girder down the slopes on either side of each reservoir.

At a short distance from the reservoirs is provided a chamber in which a Venturi meter is installed for the purpose of recording continuously the volume of water pumped into the reservoirs. The plans of the entire work were prepared by Mr. W. H. Thorpe, Assoc.M.Inst.C.E., under the direction of the Hon. R. C. Parsons, M.A., M.Inst.C.E. We shall, in a further article, deal with the plant used in the construction of the reservoirs.

*(To be continued.)*

## THE INSTITUTION OF GAS ENGINEERS.

FOR the first time in the history of the Institution or its progenitors—the British Association of Gas Managers, and the Gas Institute—an autumn assembly took place on Thursday and Friday, October 17 and 18.

It was held at the Institution of Civil Engineers, under the presidency of Mr. Samuel Glover, M.Inst.C.E., who has been Engineer of the Gas Department of the St. Helen's Corporation, Lancashire, for many years. He is, with Mr. John West, M.Inst.C.E. (to whom the Institution awarded the high distinction of its "Birmingham Medal" last June), the joint inventor of the Glover-West system of vertical retort carbonisation, a system in operation not only in Great Britain but in all parts of the world.

That the calling of the meeting was amply justified was evident from the completely filled hall. The members were attracted by the high importance of the subjects down for discussion: (1) The proposed reconstruction of the National Gas Council; (2) the Preliminary Report of the Gas Investigation Committee; (3) the Report of the Life of Gas Meters Research Committees (in the form of two contributions—(A) "Unaccounted-for Gas," by Mr. B. P. Parkinson, and (B) "The Corrosion of Dry Meters," by Mr. J. G. Taplay, chief analyst to the Gas Light and Coke Company); (4) Report of the Refractory Materials Research Committee, consisting of a communication on "The Corrosive Action of Flue-Dust on Fire Bricks," by Mr. Walter Emery and Dr. A. Scott, of Stoke-on-Trent, where

the Research Committee's investigation is being conducted, under the supervision of Dr. J. W. Mellor.

### Gas Investigation Report.

The president, before calling upon Professor Smithells and Professor Cobb to introduce the Report, said that he ought to explain in a few words something of the history of this undertaking by the Council of the Institution.

In 1917 the Council decided that it would be in the interests of the industry if a systematic enquiry were set on foot to determine the heating and lighting efficiency in actual practice of different grades of gas, and especially of the grades which had been called into use by the exigences of the war. For, although there existed a good deal of information, and a good deal of confident opinion on the subject, it was evident that the whole matter had really never been as fully and systematically investigated as was desirable. Having arrived at this conclusion, the Council directed that the task should be undertaken by the Committee which had been working at Leeds on the subject of heating and ventilation. This Committee was composed of gas engineers and representatives of the University of Leeds, and was requested to take up the new work; it forthwith proceeded to plan an investigation and make the necessary preparations for carrying it through.

This took place before the Government had constituted a fuel research board under Sir George Beilby, F.R.S. Soon after the creation of the Fuel Research Board the Board of Trade called a meeting of representatives of the gas industry, including the Gas Referees, Technical Societies and Gas Consumers' Representative to meet Sir George Beilby with a view to his eliciting opinion as to the quality of gas supplied to the public, especially with respect to the proportion of inert constituents.

At this meeting it was revealed that it was not easy for some of the interests represented to give their opinion with the definiteness indicating conclusively what they wanted and what they did not want. Representatives of gas manufacture felt themselves quite unable and unauthorised to make definite statements on so highly controversial a subject, and one which the Institute of Gas Engineers had initiated; experimental enquiry was therefore instituted with the object of obtaining reliable data which they believed to be lacking and yet to be essential for the formation of a sound judgment.

As the question of the type of gas which under existing and impending circumstances it would, on the whole, be best to aim at supplying for all purposes was a very complex one involving much more than the Council had referred to its heating and Ventilation Committee, the Council appointed a larger Committee under the title of the Gas Components Committee. This Committee, whose name had given rise to some misunderstanding, was renamed the Gas Investigation Committee, and it incorporated with itself, as a Sub-Committee, the Committee which was already engaged in experimental work upon the heating and lighting efficiency of different grades of gas.

The Sub-Committee had from time to time reported to the Gas Investigation Committee, and although its enquiries were by no means completed, it was felt by the Council that, having regard to the subject of the enquiry, they might with some advantage make known to the members of the Institution the general character of the results so far as they went. The preliminary report of these results would be open for consideration that morning, and it was an account of these results that Professors Smithells and Dobb would deal with.

Another very important branch of work had been undertaken by the Committee, in addition to that which was being done by the Sub-Committee, and that was an investigation of the work and results obtained at the Uddington Gas Works, which works had been offered for this purpose by the kindness of the Gas Company there and of their Engineer, Mr. Laurence Hislop.

Professor Cobb following the words of Lieut.-Col. Smithells in the introduction of the report said:—Col. Smithells has belittled unfairly the share he has played in the work of the Gas Investigation Committee, and particularly in that of the Research Sub-Committee. He had been present at nearly every meeting, often at great inconvenience to himself, has displayed throughout the keenest interest in all that has been going forward and been most helpful in many ways. In his introduction to the report as Chairman of the Research Sub-Committee, Col. Smithells has made quite clear the position of the Committee with respect to this investigation, but he [the speaker] would like to add some further explanation of what they have attempted to do. The original proposal for this enquiry was made at the end of 1916. Since that time its importance had become more obvious every day. The necessity for the conservation of our fuel resources, and the more complete utilisation of the thermal, and also the chemical, value of coal, was now receiving Government recognition, and the working of the carbonisation process with the maximum degree of efficiency was one of the most essential parts of any such conservation. In the first place the gas industry should itself be able to make definite statements as to what was the quality of gas which combined best the two qualities of economy in production and efficiency in utilisation. The work which the Research Sub-Committee set itself was the determination of the relative efficiencies of different grades of gas in use. There was no consensus of opinion possible, unless and until careful, comparative experiments gave some firmer basis for it, than any which was in existence. The enquiry has been limited, on account of time, to the investigation of gases which might reasonably be regarded as coming in the range of gas works practice, and the tests have been carried out on what was regarded as representative of existing appliances. The Report must be read with that proviso in mind.

The first part of the work, on methods of testing, was carried out in the University Laboratories at Leeds. The second part had, so far, been carried out at the works of the Birmingham Corporation Gas Department. They had given the Committee every possible facility.

Both low-temperature and high-temperature uses of gas, were tested taking as three types of apparatus in use the ring-burner, the gas fire, and the incandescent mantle, which among them covered a very large proportion of the gas consumed. They were all rather surprised to find the extent to which the efficiency in use of the gas-fire, and, even more so, of the ring-burner was dominated by the number of calories supplied to it, and how little it was affected by the grade or composition of the gas.

With respect to lighting, nearly all the tests had been made on the upright incandescent burner, and in this application, the grade of gas seems to have a much more marked effect on the efficiency obtainable. The results brought out among other things, the insuperable difficulties that would arise in applying as a criterion of quality, the flame temperature, which had been so often recommended. In the first place the richer gases required more air for their combustion, so that the difference between the mixture of gas and the air ready for combustion from one gas and that from another was nothing like so great as that between the two original gases. The chief difficulty, however, arose from the composite character of the flame, and the fact that the illuminating power of a mantle depended upon the intensity of combustion, not of the flame as a whole, but along the particular thin shell mapped out by the mantle itself. The temperature of the flame, therefore, came to be of minor importance, over a wide range, compared with the power which the flame possessed to fit the mantle and so exert its maximum effect. His personal impression was that the best definition of the quality of gas all round would be made simply in terms of its gross calorific value per cubic foot, but he would emphasise that this was an individual impression and that the Report itself was of a preliminary nature. The inverted burner, the gas engine, and industrial furnaces, still required attention. It was plain that when it made any recommendation as to Standard the Gas Investigation Committee would have to take into account the efficiency of gas in all its chief applications, as well as in the economy of production.

Finally he would like to call attention to a subject which did not form part of the report before the meeting, but was closely connected with it. They had been concerned so far with the efficiency of gas in use, but comparative economies in production—the efficiencies of various gas-making processes—were of equal importance.

That was a different line of investigation which could and should be followed up separately and without delay. The Council has authorised the appointment of a second research chemist for that purpose. It was proposed to start that branch of work at Uddington where, through Mr. John West, Hon. Member of the Institution, valuable facilities had been offered by Mr. Laurence Hislop and his Company. The Research Sub-Committee has co-opted Mr. Hislop, and would have the great advantage of his collaboration while the work was being carried out at Uddington. This would be of great service to them in enabling them to investigate gas production in continuous vertical retorts, and those developments of carbonisation which depended upon the treatment of the descending charge by an ascending stream of gas.

Mr. James W. Wood, Research Chemist said:—It was necessary in the first place to obtain a clear idea of the scope of the Report, and its limitation. During recent years there had been a tendency to reduce the calorific value of gas supplied to the public, and the views put forward by those whose opinions carried weight, for and against such reduction, were very conflicting. Under such circumstances, the only way of obtaining a satisfactory solution was by actual trial of various grades of gas under strictly comparable conditions. The problem to be investigated, therefore, was that of the efficiency, in use, of gases of different grades and compositions when made. The last two words imposed an important restriction. The economics of gas production was a branch of the subject, equally important, but outside the scope of the present investigation, and, beyond dealing with gases which could be readily produced under works conditions, no attention had been paid to this important collateral subject. The relative efficiencies of various type of existing appliances, of modification of such appliances also, had been left alone for the present. The problem would have been relatively simple if it had only been necessary to test a series of gases of successively decreasing calorific value. But, it must be borne in mind, that efficiency in use might depend upon other factors than calorific value, inasmuch, that the same calorific value might be obtained in a variety of ways. Thus, broadly speaking, they might have two classes of gas mixtures (1) those in which practically the whole of the mixture was combustible, as obtained when high-grade coal gas was diluted with good quality blue-water gas and (2) mixtures of the same calorific value obtained by diluting high-grade coal gas with producer gas, with furnace gases by "over pulling," or with air, in which case the gas mixture contained more or less "inert" matter. The question of "inerts" was one which at the present time ranked only second in importance to that of calorific value itself.

The tests had all been carried out with what were regarded as good representative types of existing appliances, with no adjustments beyond those supplied by the makers. The conclusions and recommendations of the Report were therefore limited by that consideration. Where gases had proved to be inefficient, they were not, of necessity, finally condemned, since it might be that slight alteration in design of the appliances would bring such gases within the sphere of successful utilization, but it was only reasonable that they should deal, in the first place, with appliances as they now found them. In every case an attempt had been made to develop the maximum efficiency of the gases concerned, to which end great caution had been exercised in avoiding the use of rigid "standard conditions." The suitability of various grades of gas had been examined in the case of:—

(a) The ring burner (essentially the gas cooker).
(b) Incandescent lighting.
(c) Gas fires.

Industrial heating and gas-engine work were contemplated, but had not yet been undertaken.

Part I of the report dealt with ring burners, i.e., practically the situation as it affected the gas cooker. For purposes of comparison a simple water-boiling test was adopted, carried out in a practical manner, the details of which were embodied in tables. In passing, it was worth while noting the manner in which the results were expressed and certain advantages of this mode of expression. It is known that to heat 8 lbs. of water from 60 deg.–212 deg. F. required 1216 British Thermal Units. Theoretically therefore thermal efficiency would be represented by the fraction:—

$$\frac{\text{Heat supplied by gas during heating from 60 deg. to 212 deg. Fahr.}}{\text{Heat theoretically required, i.e., 1216 B.T.U.}} \times 100 \text{ p.c.}$$

Since the heating curve was practically a straight line, the efficiency value would remain unaltered if the temperature range were changed to any other value *e.g.*, 32 deg.–212 deg. F., since the value 1216 would become correspondingly changed.

Similar reasoning applied in the case of alteration in the quantity of water used for a test. Conversely, given the thermal efficiency, it was easy to calculate the heat which must be supplied to perform any specified operation since this was merely the fraction heat theoretically required.

At the outset is was assumed that thermal efficiency might be affected by the type of burner, quality of gas, rate of gas supply, degree of aeration, duration of heating and distance between burner and kettle. Preliminary experiments were therefore made with one burner and one *quality of gas* in order to determine the relative importance of each of the above factors, before adopting "standard" conditions for subsequent tests. The results were given in the Report. The burner would appear to have an efficiency of about 53·5 per cent. on the net calorific value, when placed 1 inch below the kettle and consuming gas at 12·24 cubic ft. per hour. In the table individual efficiencies would be noted which were higher than this, but they were obtained under conditions which could not be recommended for domestic practice. Perhaps the most noteworthy feature of the results was the drop in efficiency from 53·5 to 43·5 per cent., when the distance between burner and kettle was increased from 1 inch to 2 inches. Flame-contact would seem to be the essential feature for high thermal efficiency, heating by hot air, or products of combustion being relatively inferior.

It was possible to bring a vessel too close to the burner in attempts, to secure good flame contact, thereby causing smothering of the flames, poor ventilation, and inability to get rid of products of combustion, with consequent falling off in efficiency. There was no desire to recommend or stipulate standard distance between burners and vessels. This must of necessity change with the type of gas, type of burner, degree of aeration, and normal gas consumption and was a matter for trial. The attention of manufacturers was however called to this important point in gas cooker design.

It was important to note that greater differences in efficiency had been obtained with one burner and one gas, by varying the mode of application (*within reasonably practicable limits*), than had been obtained by the use of different burners and widely different qualities of gas. It would thus be seen that some of the irreconcilable figures which have been published from time to time might quite easily be due to slight differences in manipulation, the possible effects of which have been overlooked.

The preliminary experiments led to the conclusion that the best conditions for working were as follow:—that the burner should have fairly well aerated flames, and placed sufficiently far apart to be separately visible when the burner was in use and the best possible flame contact should be secured compatible with satisfactory aeration and ventilation of the flames. Further it was decided that a rate of heat supply corresponding to 675 British Thermal Units net per hour, would represent the normal working capacity of the burner.

The main tests were then proceeded with upon this basis, but tests were made at higher and lower consumptions, to be certain that the conditions deduced from the preliminary tests were not peculiar to the gas of 530 British Thermal Units gross alone. The results were collected for different grades of gas from 530 British Thermal Units gross to 241 gross and with total inerts from 18·7–51·7 per cent.

The conclusions were as follow:—

*With respect to Ring Burners.*—(1) The conditions suitable for obtaining the highest efficiency from a particular burner were stated in some detail.

(2) The results obtained from particular gas depend upon the number of heat units supplied. Provided suitable adjustments were made, the efficiency was practically independent of composition, inerts, or calorific value. As a matter of practical convenience, to deliver a sufficient number of British Thermal Units in a reasonable time without abnormal pressures the gas used should be of moderately high calorific value.

(3) The conclusions outlined above depended presumably upon the fact that the difference between the temperature of the water (even at its boiling point) and that of the flames of any gas mixture which has been tried, was so great that the variations in flame temperature met with in practice were negligible in effect.

(4) The addition of air to the gas at the holder (Series 5) did not give better results than those obtained with a properly adjusted burner, working in the ordinary way, whilst the pressure, &c., required to deliver the same number of heat units and do the same heating was increased.

(5) The efficiency of ring burners properly adjusted and using the same gas varied considerably with the type of burner employed.

(6) When the gas quality was sufficiently reduced, lighting back occurred with most ring burners in common use, but the limit varied considerably with the design of the burner. It varied from 500 British Thermal Units gross to 400 British Thermal Units gross in these experiments.

(7) A wide variation in grade or composition of gas could be made with reference to other purposes, without impairing the efficiency of ring burners now in use.

Part II of the report dealt with the ordinary low pressure upright incandescent burner. A burner of good modern and widely used type was chosen with good provision for gas and air adjustment.

The familiar Letheby Bar Photometer was used for testing, and a series of tests was made for each gas at different consumptions; for values well below to well above the normal consumption for the burner. When plotted in curves it was thus possible to see the variation in the efficiency with consumption and to smooth out the errors of individual determination.

Since the report was written up further tests have been made with a different type of burner. The general conclusions still held perfectly good, but the limiting values were different. We could find a gas which was too rich (above 580 British Thermal Units) and one too poor and an intermediate range, over which the gases gave satisfaction. This only pointed to the fact that a reasonable survey must be made, not only of gas qualities, but of existing appliances before rigid specifications can be made for gas quality.

The feature of the lighting section which required emphasis was this: the production of light involved the consumption of heat, and it was absolutely essential in the first place to supply the requisite number of British Thermal Units. Further it did not follow that because the requisite number of British Thermal Units were supplied at the burner head a satisfactory illumination would result. The British Thermal Units must be supplied in exactly the right place, i.e., they must be developed in contact with the mantle.

Part III of the report dealt with the gas fire. The radiant efficiency in this case was taken in place of the thermal efficiency and the test was carried out by the method originally developed by the Gas Heating Research Committee of the Institution of Gas Engineers. Improved instruments and some modifications of the original method had been introduced. The section was still very incomplete and it was unfortunate from the point of view of obtaining strictly comparative figures, that the same gas fire could not be used for all grades of gas. The gas fire, as at present designed, did not possess sufficient flexibility for dealing with widely different qualities of gas. In conclusion it must be emphasised that this report was only a preliminary report; that much new ground has had to be broken, and that the investigation was still going forward in a satisfactory manner.

Mr. James W. Wood, chemist to the Research Committee, in his reply to the discussion on the Report of the Gas Investigation Committee, said that since the remarks and criticisms by the various speakers tended on the whole in one direction it would simplify matters to reply to the points raised rather than to answer individual speakers. Perhaps the chief complaint was that the efficiencies given in various parts of the report were somewhat low; that such figures might be quoted against the interests of the gas industry, and that they had not employed those types of appliances capable of developing the highest efficiencies with the gases concerned. To follow out the latter idea in a thorough and logical manner would probably involve tests of many appliances, and, the selection of a few of them for use over limited ranges. Professor Smithells, Professor Cobb and Dr. E. W. Smith had pointed out, and it could not be too strongly emphasised, that they were testing the relative efficiency in use of various gases, and not of appliances. For this purpose they must deal in the first place with typical existing appliances, and, in spite of one very emphatic statement to the contrary, they had employed the actual burners and appliances used by many consumers. It would, of course, be unwise to detach any of the statements or figures from their context and the careful reservations which had been made. It was not the intention of the report to deny or to belittle the importance of flame temperature. It was a conception easily grasped, the 'theoretical flame temperature' was moderately easy to define, but the difficulties in the way of obtaining a figure which was more than a mere scientific abstraction were very great. Even if this quantity could be accurately determined, the points brought out in the report would still hold good, namely, that differences in the manner of utilisation and application of the gas might neutralise or entirely discount advantages due to a higher flame temperature. There was some surprise shown at the meeting when the air supply was placed in an important position in connection with the gas engine design. For those who could read between the lines there was evidence in the report that air supply occupied a very important position in connection with the tests. The heat units in the gas were potential and could only be realised when burned with an appropriate air supply. This was one of the reasons for the improvement met with in many burners when the quality of gas had been somewhat reduced. Thus, with a particular burner the tests show a gas of 480 British thermal units gross to be superior to one of 625 gross. It was easy to assume a progressive decrease in efficiency between the two limits, but examination of intermediate qualities shows a maximum at 525 British thermal units.

He would like to remove one slight misunderstanding and put forward a warning. The view had been put forward that, provided proper precautions were taken, the efficiency in use of various gases was about the same, and was substantially independent of quality. It would be unwise at this stage to dogmatise upon the subject. A word must be said in defence of the use of the radiant efficiency only, in connection with gas fires. The flue losses and the heat conducted or convected into a room with a particular fire were likely to be moderately constant. The radiant efficiency on the other hand was the most likely to suffer change (if any) with change in gas quality. It was therefore given, not as an expression of the total heating efficiency of the gas fire, but as a possible index to changes in efficiency. Finally, the report, as befitted a preliminary report, suggested no limits of quality other than those found suitable for the appliances that had been used. Tests were in progress with those gas mixtures so peculiarly interesting at the present

# ELECTRIC TRACTION ON THE CENTRAL ARGENTINE RAILWAY.

MESSRS. MERZ AND McLELLAN AND MESSRS. LIVESEY, SON, AND HENDERSON, ENGINEERS, LONDON.

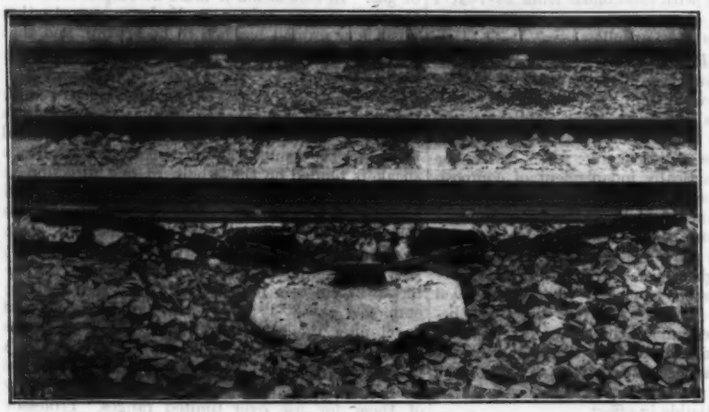
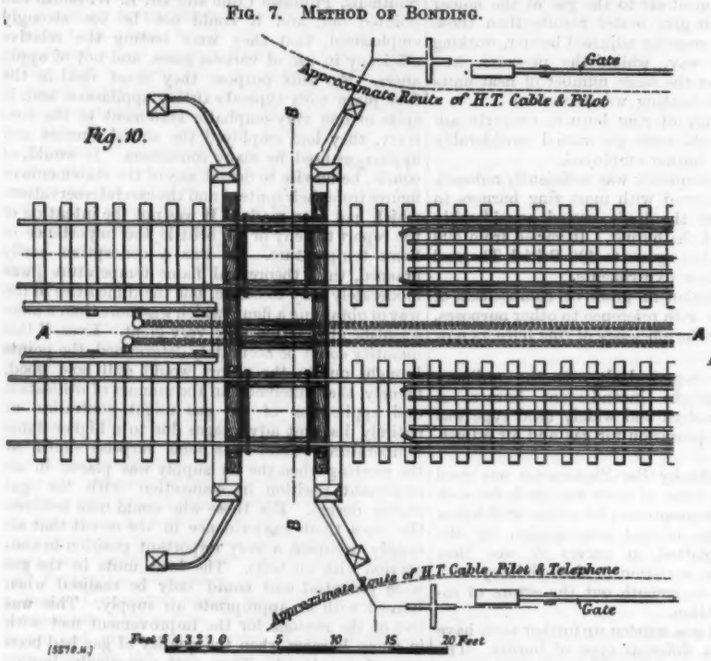


Fig. 7. Method of Bonding.

Fig. 8. Conductor Rail and Ramp.



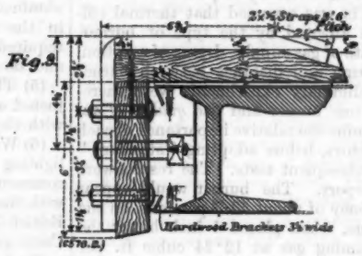




Fig. 11. SECTION A.A.

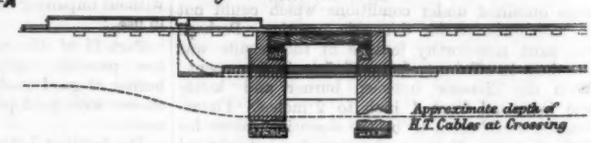



Fig. 12. SECTION B.B.

Fig. 9. Conductor Rail. Figs. 10 to 12. Level Crossing and Cattle Guard.

time, namely mixtures of coal gas and blue-water gas."

The president interrupted the discussion of the Life of Gas Meters Research Committee in order to ask the meeting to authorise the despatch of a loyal telegram to the King, and to assure His Majesty of the Institution's determination to continue its efforts in the production of the elements needed for the supply of high explosives to the forces on and under the sea, on land, and in the air. A gracious and appreciative reply was subsequently received. The president then called on Sir Guy Calthrop, Bart., to address the meeting.

### Coal Conservation.

Sir Guy Calthrop said: It was a great pleasure to him to be there. He was grateful to the gas industry for its assistance. He knew that the adoption of 15,000 cub. ft. of gas as the equivalent of a ton of coal in the Fuel and Lighting Order was much criticised. Whether they agreed with him or not, he was glad to have noticed that all their criticism had always been of a constructive and not of a destructive character. His department had to hold the balance even throughout the country for the benefit of our country and all her Allies. The gas works at some distance from the coalfields would this winter have six weeks' stock of coal sent to them to carry their peak load. Four months' stock would be given to those works nearer the coalfields. The Coal Controller's Department would have liked to have done better. It had done its level best.

(*To be continued.*)

## ELECTRIC TRACTION ON THE CENTRAL ARGENTINE RAILWAY.

(*Continued from page* 431.)

### Electrical Equipment of Track.

The electrical equipment of the track (Table VI) comprised the bonding of the track rails, the erection, bonding and protection of the conductor rails, the laying of interconnecting cables across gaps in the conductor rail and the provision of switchgear for dividing up the track into short electrical sections.

*Sundry Works.*—In connection with the electrification scheme, a number of works were carried out which represent important betterments of the track. Thus the whole of the route has been fenced with wire netting. On a length of about a mile, near Tigre, which was frequently flooded, the track has been raised above flood-level. There are 75 level crossings on the route, and in order to prevent people and animals from straying on the line at these places special "cattle guards" were installed. A cattle guard (Fig. 10, 11 and 12) consists of a trench dug across the tracks parallel to the road with brick retaining walls and concrete invert. The depth varies, the standard being about 7 ft.; the width is 6 ft. 6 in. The track rails are carried across on wooden beams having the upper corners chamfered off to reduce the foothold. The fences are carried up to the trench and a footway with a locked gate is provided for the use of the maintenance gang.

Other incidental improvements were the provision under every rail of four sleepers of extra length to carry the insulators, and the installation of new track fish plates.

*Track Bonding.*—The track rails are used throughout for the return circuit of the traction current; they weigh 85 lb. per yard and are part 40 ft. and part 33 ft. long. The joints were bonded with two copper bonds of the ribbon type with solid heads giving a total cross-section of ½ sq. in. of copper and making the ratio of conductiveness of 6 ft. of rail including and excluding a bonded joint about 3 to 5. To reduce the risk of loss by theft the bonds are fixed under the fishplates. This involved the provision of new fishplates with sufficient clearance for the bond between the plate and the web of the rail (see Fig. 8). The bond holes were drilled with ratchet drills without interfering with traffic and the bonds were fixed by hand-operated screw compressors. A few pin-type stranded bonds were used at special work of manganese steel, the bond holes being drilled at the maker's works and painted with spirit varnish to prevent rusting. The two rails of each track are cross-connected every 100 yards with stranded copper bonds carried in

wooden troughs fixed to the sleepers. Adjacent tracks are cross-bonded every 100 yards.

In the Retiro terminus the rails are used for track-circuiting with alternating current. To permit of using the same rails as a path for the traction current impedence bonds are placed at the ends of the track-circuiting sections, these bonds consisting of heavy choke coils contained in oil-filled cast-iron cases, which are placed between the sleepers. Where crossings occur only one rail of each track is used for the traction current.

The routine maintenance of the bonding consists of the removal of the fishplates and an examination for broken strands. This work is organised to extend over twelve months. In addition, resistance measurements of the joints are taken every six months by means of an Evershed and Vignoles' bond tester.

*The Conductor Rail.*—Trespassing on the railway tracks is much more prevalent in the Argentine than in this country, so any form of conductor rail adopted must be particularly well protected from the risk of people touching it. It was felt that the common form of flat-bottomed rail with side boards attached to it was too exposed on the top to be safely used, and it was not possible to provide top cover or adopt the American type of under-running rail on account of the limited space available between the structure and load gauges. The form of rail shown in Fig. 9 was ultimately selected as occupying the minimum space consistent with proper clearance and as permitting of a very complete insulating covering. The rail was rolled without difficulty in high-conducting steel, and can be handled without any tendency to distortion. To save space in shipping, two rails were nested together, oak distance pieces being put between them and bolts being passed through the fish-bolt holes. Before leaving the works the rails were dipped hot in bitumastic solution to prevent rusting; when the service started up a special skate with scraping edges was fixed to the collector shoe gear on a coach which was hauled up and down by a steam locomotive till the contact surface of the rail was clean; hand scrapers were also used.

The fishplates are single and applied to the back of the rail, the bolt-heads being countersunk in the head to leave a free passage for the toe of the skate. Two bonds with solid plug heads are fixed under the fishplate giving a cross-section of 0·33 sq. in. of copper at each joint.

Where gaps occur the rails finish off with cast steel ramps, 5 ft. long, shaped to guide the skate into position without jarring (Fig. 8).

The rails and ramps are covered with a protection of creosoted wood boards built up in the shops and fixed in position on the ground by hammering over the ends of steel strips to embrace the edges of the top table and foot of the rail. The protection has proved very efficient, no case of fatal injury from shock having occurred up to date, though barefooted boys have been seen to run about over the rail and men have used it as a barrow plank.

The rail is carried on malleable-iron castings cemented into porcelain insulators which stand on the ends of specially long sleepers and are fixed to them by malleable-iron clips. The sleepers are of Argentine hardwoods, which are very difficult to drill and cut. They are not finished very square, and in order to provide a flat, soft bearing, and to allow for the running rail sinking into the sleepers, packing pieces are placed below the insulators, consisting of creosoted pine boards ½ in. and ¼ in. thick. The insulation of the rail is very good, the usual weekly figure for leakage from the 50 miles erected being between 1 ampere and 1·5 amperes.

To prevent creepage every length of conductor rail is anchored, and no length exceeds half a mile. The anchors are of three types:—

(*a*) Insulated links attached to a plate either fixed in a block of concrete or fastened down to a sleeper; these are used on long lengths of rail. (Fig. 7.)

(*b*) Clips on the foot of the rail which bear against the cap of a special insulator; these are used on lengths of rail up to 700 yards.

(*c*) Clips on the rail which engage the lug on a standard insulator; these are used for anchoring one or two rail lengths.

Where the rail is cut to leave room for expansion (say ¼ mile from an anchor) a short length of rail is mounted behind the gap and bonded to the main rails with stranded bonds.

*Track Cables.*—When a conductor rail continuity cable crosses under the track it is carried in a cast-iron trough bolted to an old sleeper. At cattle guards the cables are carried in iron troughs supported by old rails.

All positive cables finish in terminal pillars consisting of cast-iron bends, into which a fibre sleeve is slipped, the cable being threaded through and the core being sweated into a gun-metal cap resting on a porcelain insulator fitted into the top of the bend. The cap has bolted to it a terminal plate with sockets for stranded bonds which make connection with the conductor rail. The cap and terminal are surrounded by a potware cover which prevents a person walking past from coming accidentally in contact with live metal.

*Track Sectioning.*—The conductor rail is so divided into sections by switches mounted in signal cabins that the signalman can quickly isolate any faulty section, leaving the rest of the system unaffected. The sections are also so arranged that in case of, say, a derailment at one place any route which would be available for self-propelled trains is also available for the electric trains. Provision is made for paralleling the "up" and "down" conductor rails in order to make full use of their combined conductivity. The sectioning switches are normally of the 1,000 amperes quick break knife type; interconnecting switches and those feeding the tracks in Retiro terminus are automatic circuit breakers. Emergency switches are provided at the crossovers at wayside stations to allow of trains discharging passengers and setting back to the other line when a fault occurs beyond the platform in a section containing several stations. Sidings and the platform lines at Retiro are controlled by switches mounted in cast-iron boxes with a danger signal showing when the switch is closed.

*Track Maintenance.*—A complete outfit of insulated tools is provided to permit the maintenance gangs to change insulators and pack sleepers without having to make the conductor rail dead. The list includes:—

Rubber gloves.
Rubber mats.
Augurs insulated with rubber tube.
Spanners insulated with rubber tube.
Spades insulated with rubber tube.
Wooden covers to go over the conductor rails, when the protection is removed.
Earthing bar for connecting the third rail to the track rail.

The electrical equipment of the track is maintained by seven gangs of five men each; one of these men is charge-hand and another is an examiner who goes over his section every day and reports matters requiring attention.

FIG. 13. THE CAR SHED.

TABLE VI.—*Details of Electrical Equipment of Track.*

| | | | |
|---|---|---|---|
| Conductor rail (make: North-Eastern Steel Company's high conductivity steel). | | | |
| Weight per yard | ... | 36 lb. | |
| Length of rail | ... | 33 ft. | |
| Composition | ... | | Per Cent. |
| | | Carbon ... | 0·03 |
| | | Silicon ... | nil. |
| | | Sulphur ... | 0·05 |
| | | Phosphorus ... | 0·06 |
| | | Manganese ... | 0·36 |
| Electrical resistance | ... | 6·7 times that of copper of equal volume. | |
| Ramps | ... | Shaw's cast steel. | |
| Insulators— | | | |
| Type | ... | Doulton's single-shed round porcelain. | |
| Caps and clips | ... | Malleable cast-iron. | |
| Bonds— | | | |
| Type | ... | British Insulated and Helsby Cables Company's solid head and pin tyres. | |
| Track bonds | ... | Ribbon type, 13½ in. long, 166 sq. in. area. | |
| Conductor rail bonds | ... | Ribbon type, 6⅞ in. long, 166 sq. in. area. | |
| Cross bonds | ... | 19/·106 in. stranded, 24 in. 82 in. and 123 in. long; 166 sq. in. area. | |
| Cable terminal bonds | | 169/·0435 in. stranded, 18 in. long, 0·25 sq. in. area. | |
| Bond tester | ... | Evershed and Vignoles' type. | |
| Anchorages— | | | |
| "A" type | ... | British Insulated and Helsby Cables Company's composition insulators with shackles, plates and clamps. | |
| Sectioning gear | ... | British Thomson-Houston Company's 800-volt remote operated type. | |

## CAR SHEDS.

For the reception of the electric rolling-stock the company built a new car shed at Victoria. This shed (Fig. 13) is 230 yards long and contains 10 tracks. The rails are raised from the floor on longitudinal concrete supports so that the equipment underneath the coaches is easily got at. Power for moving the coaches in the shed is supplied from overhead trolley wires carrying little carriages from which hang cables that can be plugged into the train line sockets on the coaches. An existing shed was adapted as a repair shop by raising the roof and installing 20-ton travelling cranes.

The routine maintenance of the stock consists of a nightly inspection and a shed day once a fortnight. It is intended to give a heavy overhaul when cars come in for wheel turning, which will be for the motor coaches after running 60,000 miles to 80,000 miles and for the trailer coaches after 100,000 miles. The shed and repair shop staff consists of two shifts each of 31 men, with seven other men employed in the shops during the day only, and three rolling-stock examiners who are stationed at Retiro.

(*To be continued.*)

INSTITUTE OF ARBITRATORS.—The Institute of Arbitrators held their annual meeting on the 15th inst., at 297, Winchester House, Old Broad-street, E.C., when the retiring president, Mr. Henry Adams, M.Inst.C.E., presented the report of the council and the financial statement, which showed a satisfactory condition. Mr. H. D. Searles Wood, F.R.I.B.A., was elected as the new president and Mr. E. C. P. Monson, F.R.I.B.A., as vice-president.

THE LATE MR. THOMAS CODRINGTON.—We have to record the death, on the 21st inst., at the age of 89 years, of Mr. Thomas Codrington, M.Inst.C.E., F.G.S. Mr. Codrington served a pupilage of three years, from 1848 to 1851, under the late Mr. Brunel. He was then employed as an engineer, down to the year 1869, on a number of British railways and on the improvement of the port of St. Helier. From 1869, and for many years, he acted as principal assistant to Mr. Brereton, and was engaged in connection with harbours, docks, railways, sewerage, &c., in the capacity of resident engineer.

BRITISH MERCHANT SHIPPING.—For some time past it has been necessary in the national interest to suspend the laying down of new ships for private account during the war, and shipowners have therefore been unable to replace their losses by new tonnage. It has therefore been decided to dispose of a limited number of Government-owned vessels to owners who have lost ships by enemy action during the war, in replacement of those losses. This decision will not in any way affect the use of those vessels during the war emergency. The Ministry of Shipping is prepared to entertain applications either direct from the owners concerned or through any broker.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—The Institution of Electrical Engineers has issued the following programme of papers for the first half of session 1918–19.—1918: November 7, Mr. L. B. Atkinson—the tenth Kelvin lecture—"The Dynamical Theory of Electric Engines" (the premiums awarded for papers read or published during the past session will be presented at this meeting); November 21, Mr. J. H. Shaw, "The Use of High Pressure and High Temperature Steam in Large Power Stations"; December 5, Professor Miles Walker, "The Supply of Single-Phase Power from Three-Phase Systems"; December 19, Mr. P. Hunter-Brown, "Carbon Brushes: Considered in Relation to the Design and Operation of Electrical Machinery." 1919: January 9, Mr. M. B. Field—lecture—"The Navigational (Magnetic) Compass as an Instrument of Precision"; January 23, Mr. A. P. M. Fleming, "Planning a Works Research Organisation."

## INDUSTRIAL NOTES.

Speaking in Glasgow last Saturday, Mr. G. N. Barnes, M.P., member of the War Cabinet, said there was a keen desire for improvement in social conditions and a spirit of inquiry abroad as to how such improvement could be arrived at. That desire would be one factor in determining conditions after the war. Workmen were better educated and better organised now; they would insist upon better conditions of life. But there existed also a spirit of unrest and discontent among workers, a section of whom did not want gradual improvement, but were out for destruction, for pulling down the pillars of the State. Fortunately, this was but a small section, which did not reflect the practical bent of the people. He, the speaker, had always been against that section. In a democratic country, there was no justification for it. He believed we should succeed without that policy and without the suffering incidental to it. In regard to the schemes of reconstruction that were before the country, he expressed the opinion that we had got to pass through a very uncomfortable and even dangerous time during the next few years.

There was a great deal of talk about the restoration of trade union conditions. Some aspects of the matter could not be restored. Knowledge had come to us during the last four years, and we could not get rid of that knowledge. Therefore we could not get back to the conditions which that knowledge had superseded. Apart from that, if the demand were persisted in that trade-union conditions should be restored, then he supposed they must be restored. For his part, he would think ill of his fellow trade unionists if they demanded anything of the kind, because, after all, the restoration of trade union conditions affected merely the interests of one class, and only a small class of the working people. During the last four years men and women had gone into the workshops, and the women especially had contributed enormously to the winning of the war. It would be a poor return to them to be told now: "Get to one side; we are done with you." He appealed to his fellow trade unionists to rise above their little petty sectional interests, to take a statesmanlike view, and make a bargain with the Government and the employers and say: "It is true we gave up these conditions four years ago. Industry has passed through an evolution in these four years corresponding to that it would have passed through in twenty ordinary years. We are willing now to give up these conditions of four years ago which experience has proved to be not the most efficient, and if we give them up, what we claim is that there shall be such an improvement in the conditions of labour as the standardisation of wages, shorter hours, and a voice in determining workshop conditions for all working men and women. Let us have all these, and we should say that there would be more than a *quid pro quo* for all we gave up four years ago."

He appealed to the workers he addressed to take that larger view of the position, and if they did he felt sure that as time went on, the verdict would be that they had taken a decision in accordance with the largest possible production of wealth and in accordance with their own best interests—above all, a decision that, by the time the verdict was given, would have greatly improved the conditions of all men, unskilled as well as skilled, and have contributed something to the raising of labour and the raising of life from the low plane of animal struggle on to the higher ground of citizenship.

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Sheffield branch of the British Foundrymen's Association opened the winter session with a very interesting discussion on foreign competition in the foundry trade after the war, in the course of which some very plain speaking was indulged in at the expense of both employers and men, says, *The Sheffield Daily Telegraph*. Mr. G. Ernest Wells, a member of the association now engaged at the Ministry of Munitions in London, in opening the discussion, said that the British foundryman was the most skilled in the world, but the foundries were the worst, and if he had the task of reorganising the industry to meet after-war competition he would destroy 50 per cent. of these foundries. It was impossible to expect even the most highly skilled labour to turn out a satisfactory product in such conditions. He pleaded strongly for drastic remodelling and reorganisation, and the installation of labour-saving machinery, and a more sympathetic co-operation between employers and workmen, in which the latter should be taken more into the confidence of the employers. Where such conditions existed he knew of men earning two and three times the amount of their datal wages.

Dr. W. H. Hatfield urged the need of the application of science to the trade. Mr. T. Brown condemned the conservatism of the Sheffield moulder; Mr. T. Price urged the need for better organisation in the foundry; Engineer Lieutenant-Commander Jackson emphasised the value of labour-saving machinery; Mr. W. G. Cook deprecated any lowering of quality; Mr. C. Crossland was not surprised that the workman was suspicious of the employers' new-found zeal after having for so long regarded him as a mere means to money-making; Mr. Frank Biggin saw a possibility of improving the relations between employers and men through the medium of joint industrial councils; Mr. J. G. Crowther (the branch president) quoted personal experience to show that the workmen would respond when the position was frankly explained; and Mr. Whitehouse believed the solution was to be found in the better training of the lads.

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The annual meeting of Messrs. Kynoch, Limited, was held at the Birmingham Chamber of Commerce, on Thursday, the 17th inst. The chairman, Mr. Arthur Chamberlain, J.P., presided and stated that the natural lines of extension and development for the company to follow lay in extensions in the brass and copper trade, and in certain chemical productions. In these, the company had both knowledge and experience, and were not afraid to venture. "When you come to clocks, watches, typewriters, calculating machines and suchlike," added the speaker, "which we have had put before us, and which we have considered, the proposition is entirely different. We are not again going to venture on new industries without a partner who has the technical and commercial knowledge of that particular industry, and has also a business in being proved capable of and actually earning a profit. We are willing to provide any amount of capital for development, and to give our share of general commercial and general technical ability, but we want somebody else who has a detailed technical and commercial knowledge of the trade we are going into and the goodwill of a certainty in a business already making a profit. In the meantime, so long as our reserve is invested in National War Bonds that bring in 5 per cent. return, we need not be in any undue hurry to see our money once again invested in a manufacturing industry. We cannot afford to make a mistake. There will be no more wars to set us on our feet again if we trip. Another step that we have taken to provide for the future, in common with our British competitors, is the formation of the proposed explosives and munition merger. . . . We shall be able to retain for the country certain industries that will be profitable to both the workers and the shareholders, and advantageous to those who will consume its products instead of carrying on a rather hopeless struggle against a highly-organised foreign competition."

Dealing with foreign competition, Mr. Chamberlain said it did not make being strangled any sweeter when it was done by one of our Allies rather than by one of our enemies. Any nation that was more alive and more active than we were was, as far as industrial activity was concerned, a foe, unless we also were alive, when each one, of course, helped the other. Whatever the result of the war might be, and there could not be much doubt about that now, it was certain that there had been an enormous world wastage of wealth, and the first thing the world would have to do after the termination of the war was to set to work to produce more than ever before in order to replace that loss. Until this was done, no trade prosperity could be really secured, and the nation which did most to fill up the hole would be soonest, and most prosperous. Success for any nation in the future, in the immediate future, depended more largely on production than anything else. Production was the keyword to success. It would not benefit any worker to receive higher wages unless these were accompanied on his part by an increase in his production. Without an increase in production the price of commodities would rise, and he would find himself, probably, with perhaps twice his pre-war wage, but obliged to pay double for everything he bought, so that he was no better off than before; and, remembering that other countries had already succeeded in producing, in some cases, considerably more than we produced per head of population, it was absolutely necessary that our output be brought up to theirs, or we were doomed to become a second or a third-rate country. We were up against the old trouble of ensuring to the worker his whole share of the increased profits due to his increased production, but it was increasingly imperative that this difficulty be overcome, and overcome at once, otherwise manufacture and industry in this country would be unprofitable to capitalists and workmen alike.

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A paper by Mr. F. W. Branson, F.I.C., on "Some Aspects of the Scientific Glassware Industry," was read last Monday before the Yorkshire Section of the Society of Chemical Industry. In this, the author called attention to the co-ordinated efforts of manufacturers and merchants, in conjunction with the Society of Chemical Industry, the Board of Trade, and the Glass Technology Department of the Sheffield University, to meet an urgent national need in the supply of essential instruments of the large steel works and other industries concerned with munitions of war. He gave analytical data with respect to glass ware imported prior to the war, and described the laboratory and manufacturing methods in British-made equivalents. These were shown to be superior in quality to the best imported glass ware of pre-war time. He urged that the hollow glassware used in the works should be standardised as to shape, size, weight, &c. In order to illustrate the progress made in this country Mr. Branson remarked that several manufacturers who had entered the glassware industry since the outbreak of the war were now producing on a large scale, the output of one firm being about 1,000,000 pieces per annum.

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Mr. John Hill, general secretary of the Boilermakers' Society, in his monthly report, says, in reference to pneumatic riveting, that the agreements arrived at give six weeks in which men can get accustomed to the new tools at previous average earnings, and that there is, therefore, no reason against any of the members of his society giving the pneumatic tools a trial.

It is satisfactory to learn from the shipbuilding areas that the prejudice against these time and labour-saving tools has been to a very great extent overcome.

In a Tyneside yard recently 17 pneumatic riveting hammers were put on to one job, with the result that the work was completed in record time. This is the kind of argument that has appealed to the men. At the same time due credit should be paid to the trade delegates for their energetic support of the new method, which they have advocated at meetings held in all the shipbuilding yards.

On his recent tour of the shipbuilding centres, Lord Pirrie, in an address at Glasgow, said: "I find that one of the principal causes retarding the output of tonnage is the shortage of riveters, as vessels in many of the yards are plated and waiting for riveting. Up to a little time ago there was a certain prejudice against pneumatic riveting, but now I am pleased to state that in every yard I visited I found neither employers, managers nor workmen opposed to the introduction of this labour-saving device. My department is making special arrangements for the quick delivery of air compressors and pneumatic tools to the firms short of plant, and the local corporations are assisting in providing power." Lord Pirrie added, "I should like to acknowledge the assistance of the delegates of the trades concerned, who have been most enthusiastic in their desire to help. I feel that it is very largely due to their influence that the men have so readily fallen in with our wishes."

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The late Mr. Arthur Cannon.—We regret to have to record the death of Mr. Arthur Cannon, R.C.N.C., M.I.N.A., on the 13th inst., after a very brief illness. He was a member of the Royal Corps of Naval Constructors, and was the Admiralty Overseer on Submarine building at Messrs. Cammell, Laird and Co.'s yard, Birkenhead. He received his early training in Devonport Dockyard, and after a very successful career at the Dockyard School, obtained a National Scholarship tenable for three years at the Royal College of Science, South Kensington. After spending one year at the College of Science, Mr. Cannon decided to take up a special course in naval architecture at the Royal Naval College, Greenwich. He competed for, and was successful in obtaining, the only Admiralty scholarship awarded that year at the college. At the same time, he also won the only scholarship awarded by the Institution of Naval Architects. He completed the three years' course there with great distinction, obtaining a first-class professional certificate, the highest distinction possible. After finishing his brilliant college career, Mr. Cannon went to assist Professor Sir John Biles in his consulting work. He did some considerable work on the second volume of Professor Biles' text-book of Naval Architecture, as is evidenced in the preface to the book. In 1910, Mr. Cannon was appointed assistant to Professor Biles at Glasgow University. Although only in direct touch with the students for a limited time he rapidly became popular with them owing to his great knowledge and his unfailing tact and courtesy. At the end of 1911 the Institution of Naval Architects were in a position to award a post graduate scholarship in naval architecture in virtue of grants from the 1851 commissioners. Mr. Cannon was unanimously elected for this distinction, being the first one to hold this scholarship. The valuable research work that he carried out has been placed on record in the transactions of the Institution of Naval Architects. The Institution awarded him two special premiums for his work, and specially thanked him for the satisfactory manner in which he carried out the work as holder of the first research scholarship. In the early part of 1914, Mr. Cannon was appointed to the Royal Corps of Naval Constructors, taking up his duties at Chatham Dockyard, being transferred to the Admiralty shortly afterwards, and from there to the appointment which he held at his death. Besides being a member of the Institution of Naval Architects, Mr. Cannon was also a member of the Institution of Engineers and Shipbuilders in Scotland. All those who knew Mr. Cannon feel they have lost a good friend. He was most conscientious in his duties, and all his work was of a high order.

## THE SEMI-DIESEL OIL ENGINE.*

By JAMES RICHARDSON, B.Sc., A.M.I.C.E.

*Introduction.*—On several recent occasions, authorities, when forecasting the lines of development of the oil engine, have expressed the opinion that the so-called semi-Diesel engine would play no inconsiderable part. It might be matter for surprise that publications of technical matter dealing with the semi-Diesel engines are extremely rare in comparison with the vast amount of available data relating to the Diesel engine.

*Definition of the Semi-Diesel Engine.*—The variously-named semi-Diesel, hot-bulb or surface-ignition engine may be defined as an internal-combustion engine, using oil fuel, which has an uncooled portion of the combustion chamber, normally at high temperature, serving to augment the heat generated by the compression pressure and to assist in the vaporisation and ignition of the fuel injected at the ignition point of the cycle. From this class should rightly be excluded those oil engines which are not called by their makers Diesel engines, but which rely for ignition, as completely as the Diesel engine, upon the heat generated by the compression of the air charge, and therefore should be so named. The means of injection of the fuel with such engines may vary from the standard air injection system.

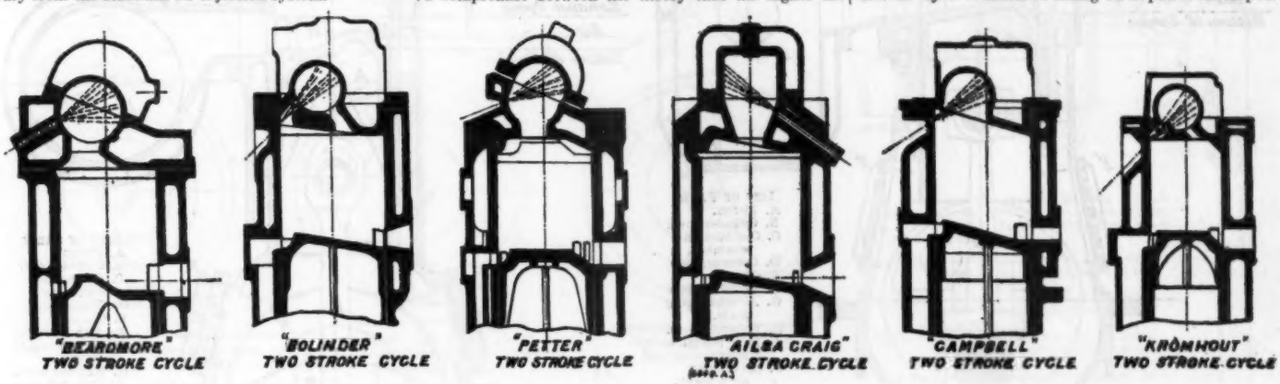



FIG. 1. NINE REPRESENTATIVE TYPES OF SEMI-DIESEL ENGINES.

*Nomenclature.*—In describing and classifying engines of the semi-Diesel type, it will be necessary generally to adopt the nomenclature and technical expressions familiarised by the literature dealing with the Diesel engine, and convenient often to describe by means of comparison with the better-known Diesel engine.

*Classification.*—The many types of engines of the type under review vary considerably (see Fig. 1) and can be classified according to the cycle of operation upon which they work, whether the two-stroke or the four-stroke cycle, and according to the extent to which the heat of compression is relied upon for the vaporisation and ignition of the injected fuel. In the present stage of development, the chief claim of the semi-Diesel engine to be considered in the forefront of internal-combustion prime movers, is its marked simplicity. Development along probable lines may reasonably and in the near future reveal qualities to gain which a certain degree of simplicity may well be sacrificed. Primarily for reasons of simplicity, the great majority—more than 90 per cent.—of these engines at the present time are designed on the two-stroke cycle principle, limited to its simplest application, and are generally confined to relatively low powers per working cylinder, 125 brake horse-power per cylinder being the maximum attained up to the present time. Fig. 2 shows cross-sections of a Beardmore two-cycle semi-Diesel compression engine and Fig. 3 of a low-compression engine, with references. Fig. 10, page 466, shows an external view of a four-cylinder engine of the same make. On the same page are external views of single-cylinder engines by Messrs. Robey and Co., Limited, of Lincoln, and by Messrs. Petters, Limited, of Yeovil. The former are made in sizes from 6 to 50 horse-power with single cylinders, and from 24 to 100 horse-power with two cylinders. Fig. 12 shows Messrs. Petters' latest type, which is made in 35 and 50 brake horse-power sizes.

Some of the earlier semi-Diesel engines used air injection of the fuel, but this type was not developed, due primarily to the disadvantage of the extra complication of compressors and their attendant gear. All modern engines of this type work with "solid" or "mechanical" injection of the fuel, because of the simplicity of this system, considered especially in conjunction with the hot bulb for assisting the vaporisation and ignition of the injected fuel. Air compressors are again making their appearance on semi-Diesel engines, although not for the purpose of air injection in the ordinary accepted meaning of the term. An air jet is used to cool the combustion chamber and piston, and so to take the place of the water-drip (mentioned later), to increase the efficiency of the scavenging of the main cylinder, and so to make possible engines of relatively high powers, i.e., over 100 brake horse-power per cylinder, without having recourse to such expedients as separate scavenging pumps, elaborate cooling systems for the main pistons, and so forth.

*Compression Pressure.*—With all internal-combustion engines, theory teaches that the higher the compression pressure the less the fuel consumption, the less the heat required from an outside source to attain to the temperature necessary for the first working cycle when starting from cold, the higher the average mean effective pressure reached in the working cylinder, and consequently the smaller the main piston-swept volume for a given indicated horse-power. On the other hand, the lower the compression the more even the turning moment, generally the higher the mechanical efficiency, and the less the effort required to start the engine from rest by way of overcoming the negative work of the first compression stroke.

The semi-Diesel engine in type is a variable compression oil engine, and can be designed to work between, but excluding, the two extreme limits—the higher, that at which the heat of compression alone suffices to ignite and vaporise the injected charge (the Diesel cycle), and the lower, that at which the size of the hot bulb becomes inconveniently large for reasons of strength, when the loss from the hot bulb, by radiation, would be a serious factor, and together with the small power output obtainable with low compression, would tend towards an excessively high fuel consumption and a large engine.

*The Disadvantage of High Compression.*—There are disadvantages attendant upon high compressions, and a compromise between the theory that the higher the compression the greater the economy and practical considerations, must be struck. In comparison with steam prime movers, the mechanical efficiency of internal-combustion engines is low, due primarily to the friction of the piston rings. (See Appendix I.) The higher the compression and consequently the maximum pressures the greater this loss on account of the larger number of rings required to ensure satisfactory gas tightness, and the greater the pressure exerted by these rings when forced against the piston walls by the cylinder pressure operating behind the rings.

A further outcome of high pressures is increased piston-ring leakage, and the effects of piston-ring leakage upon economy are very considerable. The higher the compression pressure the greater the heat transfer from the charge in the cylinder to the jacket cooling water.

*The Effect of Compression.*—From these considerations it is clear that there is a compression pressure beyond which practical considerations will cause a diminution rather than an increase in overall efficiency.

With present-day designs of semi-Diesel engines little further economy of fuel consumption is to be sought in this direction. Designers adopt various compressions according to the means foreseen for attaining flexibility and depending on whether the water drip is retained or not. The effect of increase of compression on economy between the limit of 180 lb. per square inch and 450 lb. or 500 lb. per square inch is not, *per se*, considerable, due to the practical considerations outlined. The principal effect is the possibility of sustaining higher mean effective pressures with smaller cylinders for a given output, and so attaining somewhat better fuel economy.

*Fuel Economy.*—The fuel economy of semi-Diesel engines is surprisingly good (see Fig. 4), and is accounted for by the cycle of operation being nearer to the more economical explosion cycle than to the constant-pressure burning or Diesel cycle (see Fig. 5).

*Cycle of Operation.*—Actual indicator diagrams do not quite so rigidly follow the theoretical cycle as the gas engine, on account of the difficulty with semi-Diesel engines of regulating the injection and ignition for all loads.

*Flexibility.*—Experience of the operation of internal-combustion engines teaches that this prime mover is primarily a constant speed, and to a somewhat lesser extent a constant load engine. Innumerable designs of details and countless patents have been concerned with the problem of flexibility and compromise is generally the outcome. Flexibility can be considered under three headings:—

(*a*) Constant mean effective pressure, with varying revolutions and consequently power.

(*b*) Constant speed of revolution and varying mean effective pressures and power.

(*c*) Varying speeds and mean effective pressures.

Condition (*a*) is not required in practice, and cannot normally be met, with maximum or even full load m.e.p. since with a reduction in speed of revolution, conditions affecting scavenging efficiency and compression, heat loss, &c., also change, and a small drop in speed of revolution is accompanied by a reduction in m.e.p., and so by a cumulative falling-off in power developed. A low m.e.p. can, of course, be maintained as a constant over a certain range of speed of revolution.

Condition (*b*) constant speed of revolution and varying power as affecting generator engines, &c., requires most frequently to be met, and may be considered in detail. At reduced power and m.e.p.'s—

(1) The charge drawn into the crank chamber remains relatively constant in volume or may even be slightly augmented, due to the engine running cooler as the mean effective pressure falls, unless means are provided to throttle the water cooling supply.

(2) The volume of the scavenging charge is approximately the same as at full power, but may be at a lower temperature and pressure.

(3) The compression pressure will be reduced on account of: (*a*) Lower scavenging pressure (see 2); (*b*) less heat abstracted from the cylinder walls, which in turn is due to the less fuel burnt per stroke and so the lower temperature of these walls. Condition (*c*) requires to be met with various types of machinery, and no difficulty is experienced provided the power of the engine is suitable for its work and a higher m.e.p. is not demanded than can be sustained for the speed of revolution under consideration.

Even where means are provided to throttle the cooling water and the scavenging air at low power, the point is quickly reached where the heat of the bulb is insufficient to vaporise and ignite the charge of injected oil, and the engine will "miss" and stop unless heat be externally applied to the bulb as, for instance, by the blow lamp.

*Range of Working.*—The range of working must be extended to cover from full load or overload to a small load without having recourse to the blow lamp, and for this purpose the water drip has been retained on some designs. At full load water is allowed to enter the working cylinder with the scavenging air and serves by

* Paper read before the Diesel Engine Users' Association, on Thursday, October 24, 1918.

evaporation to take heat from the bulb, so that with a relatively large bulb and a low compression engine, from three-quarters to full power can be satisfactorily developed without overheating of the bulb, and with the water drip cut off the engine will run satisfactorily down to low loads. An overheated bulb will give bad combustion and "coking" of the fuel, and is, besides, a source of danger due to weakening of the metal of the bulb (see annexed Table).

plicated gear to connect the water supply with the governor in the same way as is necessary with the fuel supply.

The better solution is to take advantage of another law which is not yet completely explained, viz., that the temperature generated within the cylinder of an internal-combustion engine depends on the load, the compression temperature, and upon the nature of the ignition, whether early, normal or late. Normal ignition may be said to be that ignition which is correct for maximum economy and will give the highest power without trouble, the cleanest exhaust, the sweetest running, &c. Late ignition makes for excessive heat losses to the exhaust and high fuel consumption. Early ignition gives rise to abnormally high temperatures. This last fact is utilised with semi-Diesel engines to counteract the cooling of the bulb with reduced power. By advancing the point of ignition of the fuel charge, as the quantity of fuel is reduced to correspond with the load, the semi-Diesel engine can be made to give satisfactorily running at all loads from full load to no load with the minimum of attention and without requiring external heating of the bulb (see Fig. 6, page 463). The governor controls the quantity of fuel to correspond with the load by varying the stroke of the fuel pump, and gears have been designed whereby with reduced quantity of fuel the injection point is advanced according either to B or C in Fig. 6. Scheme C is most necessary for engines requiring to run for long periods at light loads, whilst B suffices generally; C is less easy of attainment by a simple gear.

*Scavenging.*—The next point of importance is the question of scavenging, which, so far as published data or the results of experimental work are concerned, is almost an unexploited field, in connection with either the two-cycle Diesel or semi-Diesel engine. With two-cycle engines the efficiency of scavenging is lower than with four-cycle engines, which has proved one of the most important deterrents in all spheres of application to that success so often predicted in the past for the two-cycle principle. With two-cycle semi-Diesel engines the amount of air available per working cycle or per revolution for scavenging is limited to the volume swept by the working piston. More air than this cannot be drawn into the crank chamber (unless an induction system to the crank chamber were so designed and fitted, as to give a momentum effect with a slight gain, which subject has not yet been studied for other than high-speed four-cycle engines where the maximum output per unit volume is essential). The air, after being drawn into the crank chamber, is impregnated with a certain amount of lubricating oil, as will be discussed later under the heading of "Lubrication," and withdraws a certain heat from the working parts of the engine, especially from the piston. An indicator card and the theory of the scavenging is given herewith (see Fig. 7, page 463).

*Efficiency of Scavenging.*—Scavenging efficiency can be subdivided under two headings, the efficiency of the pump and the efficiency of the scavenging of the working cylinder. As seen from the comparison of the ideal with the working indicator diagram, Fig. 7, there are several losses in the pump:—

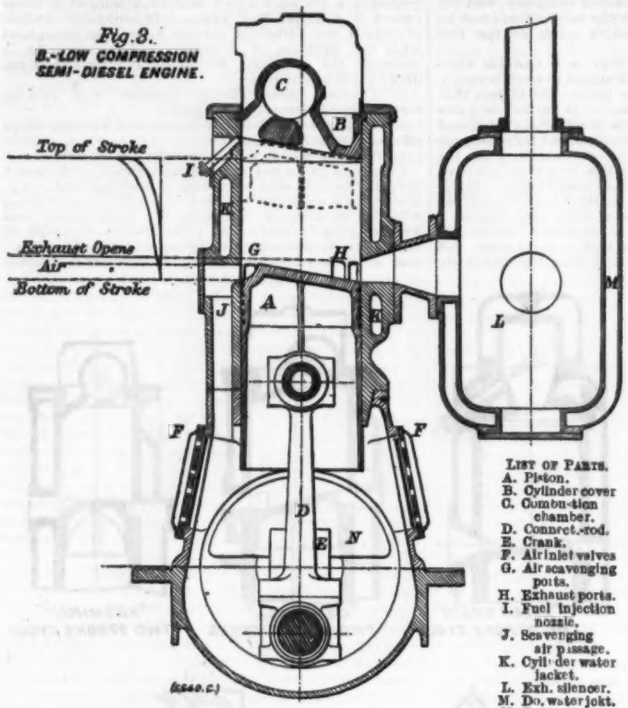
(1) Suction loss due to attenuation of the charge.

(2) Compression loss due to leakage through the main bearings.

(3) Loss of volumetric efficiency due to the heating and re-expansion of the clearance air.

To take the three points in order; suction loss requires no explanation. Loss due to leakages through the bearings is now reduced to a minimum with careful design of the air rings and good workmanship. Fig. 8, page 463, shows an arrangement which has proved satisfactory. The clearance volume should be kept a minimum although with this type of engine, this volume is always large even when the crankshaft is fitted with balance weights to give better balance and to minimise this clearance volume, and where the clearance for the crank and bottom end is cut fine, since the air must have access to the piston crown for cooling purposes. It is probable

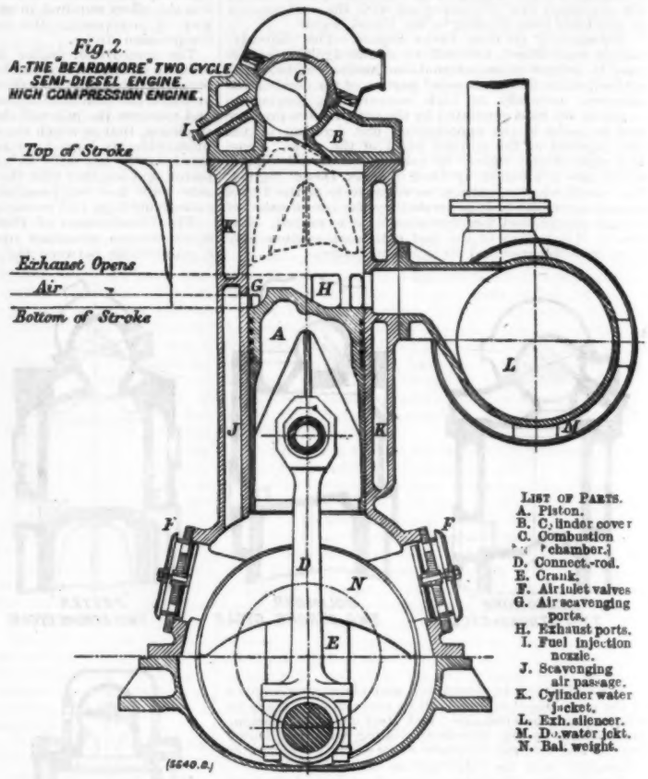
*Fig. 3.* B.-LOW COMPRESSION SEMI-DIESEL ENGINE.




(5540.C.)

List of Parts.
A. Piston.
B. Cylinder cover
C. Combustion chamber.
D. Connect.-rod.
E. Crank.
F. Air inlet valves
G. Air scavenging ports.
H. Exhaust ports.
I. Fuel injection nozzle.
J. Scavenging air passage.
K. Cylinder water jacket.
L. Exh. silencer.
M. Do. water jckt.
N. Bal. weight.

*Fig. 2.* A. THE "BEARDMORE" TWO CYCLE SEMI-DIESEL ENGINE. HIGH COMPRESSION ENGINE.

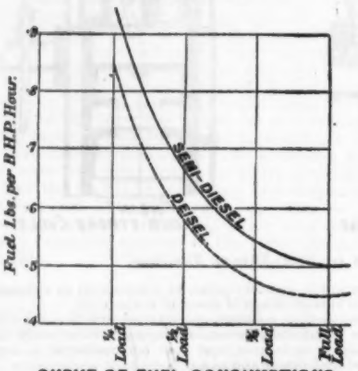



(5540.B.)

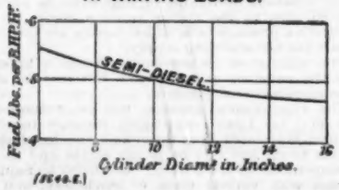
List of Parts.
A. Piston.
B. Cylinder cover
C. Combustion chamber.
D. Connect.-rod.
E. Crank.
F. Air inlet valves
G. Air scavenging ports.
H. Exhaust ports.
I. Fuel injection nozzle.
J. Scavenging air passage.
K. Cylinder water jacket.
L. Exh. silencer.
M. Do. water jckt.
N. Bal. weight.

*Fig. 4.* FUEL CONSUMPTION OF SEMI-DIESEL & DIESEL ENGINES.

NOTE:—
Fuel Calorific Value of about 18,500 B.T.U's per Lb.

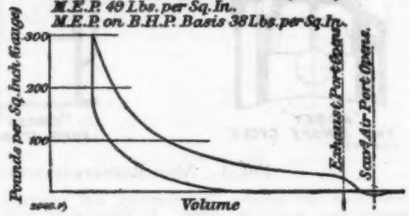



CURVE OF FUEL CONSUMPTIONS AT VARYING LOADS.




(5540.E.)

*Fig. 5.* FULL POWER INDICATOR CARD OF 2 CYCLE SEMI-DIESEL ENGINE.
Maximum Pressure 300 Lbs. per Sq. In.
Compression Pressure 185 Lbs. per Sq. In.
M.E.P. 49 Lbs. per Sq. In.
M.E.P. on B.H.P. Basis 38 Lbs. per Sq. In.




5540.F.)

*Table showing Tensile Strength of Combustion Chamber Materials at Various Temperatures.*

| Load on Engine. | Colour. | Temperature Deg. F. | Tensile Strength of Cast Iron. Tons per sq. in. | Tensile Strength of Mild Steel. Tons per sq. in. |
|---|---|---|---|---|
| Light load | Just showing colour in the dark. | 750 | 12 | 24 |
| Normal load | Between dull and cherry red. | 1,100 | 7·5 | 12 |
| Over-load .. | Bright cherry red. | 1,400 | 3·5 | 2·5 |

*Consumption of Water.*—The consumption of water through the water drip is very considerable, and varies according to the quality of attention given to the running of the engine, but may reach a value at high powers much in excess of the quantity of fuel burnt. The water should be as pure as possible to cause the minimum harm from deposits on the working surfaces. Water has a deleterious influence on the lubrication of the internal parts, although it is credited with preventing carbonising of the main piston rings. The water drip, however, is a crude solution of the problem of flexibility, requiring a large supply of fresh water, and with varying loads, regular attendance to the engine, since it is somewhat difficult and calls for com-

that the greatest loss of efficiency is not in the scavenging pump but concerns the scavenging within the working cylinder.

The effect of the shape, and the size of the scavenging and exhaust passages and ports has not been fully studied, although it can be stated that wide variations in both are possible without any appreciable effect on the performance in practice of the normal semi-Diesel engine, the main considerations being, as would clearly be inferred from the indicator card, Fig. 7, to get rid of the exhaust at a suitable point as rapidly as possible, and that back pressure of the exhaust must be reduced to an absolute minimum. Back pressure has an effect in preventing the entrance of scavenging air to the working cylinder, previously compressed to a pressure dependent in some measure upon the speed of revolution. The scavenging air pressure cannot increase to overcome exhaust back pressure as with separate valve-controlled scavenging pumps. The chief effect of back pressure, however, is to decrease the quantity of air drawn into the crank chamber to be compressed. The pressure from which the clearance air in the crank chamber must expand is the back pressure of the exhaust, and until this clearance air has expanded down to the suction pressure no fresh air will be drawn into the crank-case. The volumetric efficiency is entirely dependent upon this factor, as is clearly shown in Fig. 7. Large exhaust ports, ample passages, the close proximity of a large silencer to the cylinder and the minimum of restriction in the exhaust pipes, are necessities.

The two-cycle semi-Diesel engine has almost settled down to a standard design of scavenging and exhaust passages and piston crown without any proof other than that of satisfactory performance, although still at relatively low efficiency. Much experimental work still remains to be done on this subject. This course involves considerable labour and expense due to the large numbers of variables that have a direct influence, of which but a few will be mentioned. Piston speed must have an effect on the efficiency of both the crank chamber scavenging pump and on the cylinder scavenging. Experience has shown that 800 ft. per minute approximately is the maximum piston speed, above which with present designs the scavenging efficiency falls off somewhat rapidly, the power output from the engine fails to increase with higher revolutions and increased fuel, and the limiting condition of maximum powers are reached.

With this question is intimately associated the subject of the stroke/bore ratio; it can be said that the higher the stroke/bore ratio, the better the conditions of cooling of the piston, because the smaller the diameter of the piston for a given power, and so the shorter the path for the heat to travel from the centre to the cooled walls; also the lower number of revolutions for the desired output of power gives certain advantages for driving types of machinery which are inherently slow speed machines. Furthermore, the author's experience suggests the larger the stroke/bore ratio within the limits of ratio of 1 to 1 and 1·5 to 1, the less, probably, the escape of scavenging air through the exhaust ports, due to a greater quantity of fresh air being entrapped in the combustion chamber, i.e., with a square engine—an engine of approximately equal stroke and bore—a greater percentage of the scavenging air finds its way out through the exhaust ports.

The shape and angle of entrance to the cylinder of the air inlet passages, the type of baffle on the piston crown and the location of the bulb in relation to the path of the scavenging air all have an influence.

*Injection.*—To turn to the question of injection, which depends primarily with a solid injection semi-Diesel engine on the following factors:—

(1) Turbulence within the cylinder.
(2) Pressure of fuel and rate of injection.
(3) Point of the cycle at which injection occurs.
(4) Fineness of the spray.
(5) Distance of injector from the hot igniting surface.

These points are not given necessarily in order of importance. Turbulence, apart from piston speed which is governed as already stated by consideration of scavenging, is determined by the shape of the piston crown and the combustion chamber, and in the immediate vicinity of the spray by the shape, speed and volume of the spray. The question of turbulence is an exact parallel to that of scavenging and as yet has received little attention, excepting for the experiments arising out of the necessity to burn tar oils in Diesel engines.

The pressure of injection is governed by the piston speed of the fuel pump or by the angle of crank revolution allowed for the injection of the fuel and by the size of the orifice or orifices in the injector. Pressure is necessary more to give momentum to the stationary column of oil than to secure fineness of the injection spray. It is an absolute essential that injection shall be as rapid as possible, and the injection devices so designed that no "after drip" takes place.

The angle of revolution allowed for the injection period is governed by the ratio of diameter to stroke of the fuel injection pump which injects the fuel through a non-return valve or valves direct into the hot bulb. Obviously with a large diameter and a small stroke fuel pump the period is short and conversely. Practical considerations of design of the pump and governing mechanism determine the period for full power running to be about 30 deg. (see Fig. 6). As regards fineness of spray, no standard has been fixed, although the spray can certainly be "too fine" for rapid ignition.

The next essential is probably that the whole of the oil should be in the combustion chamber in the form of a spray before the first particle touches the hot bulb, which again is a function of rapidity of injection and of the distance through which the oil is thrown, arguing in favour of a long-distance of throw to give rapid ignition and the maximum degree of turbulence in the vicinity of the spray, although a long throw will militate against flexibility. The efficiency of the scavenging will determine to what extent the hot bulb is charged with burnt gases or with fresh air, and will thus have a direct influence upon the speed of ignition and combustion.

*Fuel.*—In view of the simplicity of this type of engine in comparison with the usual four-cycle internal-combustion gas or Diesel engine, it might be matter for surprise that the semi-Diesel engine has not made greater headway in the past than has been the case. The one outstanding difference between the semi-Diesel and the Diesel engine has been the small range of working fuels with which it could satisfactorily cope. It is but a few years since the great majority of these engines almost required paraffin or the very lightest of petroleums for their successful operation in practice with reasonable costs for upkeep and maintenance. Recently, however, the advantages of simplicity of this engine have been more generally recognised and have led its producers to experiment on the question of utilising fuel oils of a

DIAGRAM ILLUSTRATING THE CONTROL OF THE POINT OF COMMENCEMENT AND PERIOD OF INJECTION FOR VARYING QUANTITIES OF FUEL AND LOAD, GIVING CORRESPONDING INDICATOR DIAGRAMS.

Fig. 6.

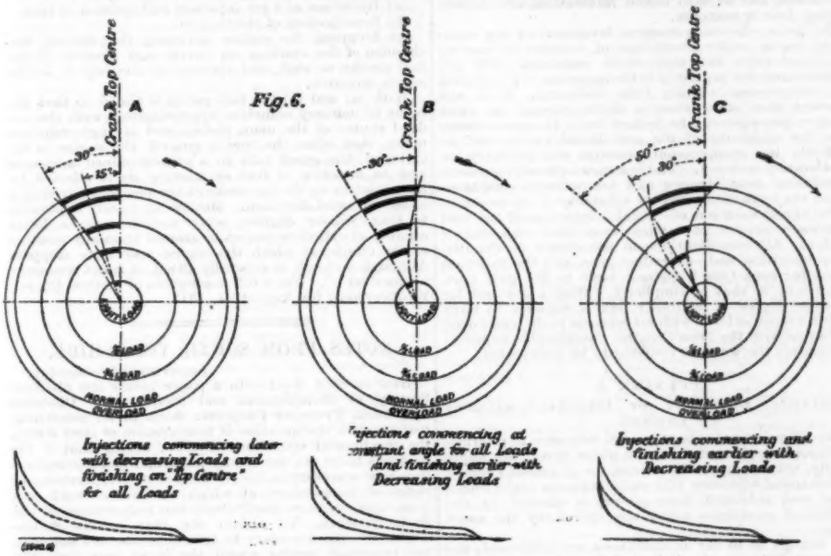
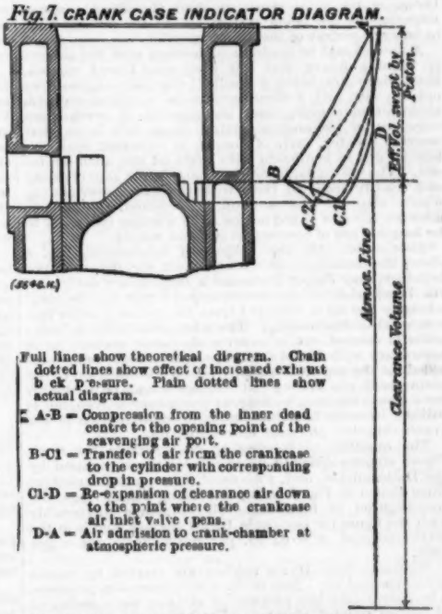



Fig. 7. CRANK CASE INDICATOR DIAGRAM.




Full lines show theoretical diagram. Chain dotted lines show effect of increased exhaust back pressure. Plain dotted lines show actual diagram.

A-B = Compression from the inner dead centre to the opening point of the scavenging air port.
B-C1 = Transfer of air from the crankcase to the cylinder with corresponding drop in pressure.
C1-D = Re-expansion of clearance air down to the point where the crankcase air inlet valve opens.
D-A = Air admission to crank-chamber at atmospheric pressure.

Suction loss due to attenuation of the charge is shown by the air admission line of the actual diagram falling below the atmospheric pressure line. The actual compression line is below the theoretical A B, because compression commences at a lower pressure and on account of leakages. Volumetric efficiency of the scavenging pump is greatly affected by the exhaust back pressure, as the position of the point C1 controls the position of the point D, as shown. The chain dotted line shows the effect of increasing the exhaust back pressure from C1 to C2. The further D is from A the greater is the volume of air represented and dealt with in the crank chamber. Exhaust back pressure affects the quantity of air transferred to the working cylinder, but has no influence on the scavenging air pressure.

ARRANGEMENT OF RINGS FOR SECURING AIR TIGHTNESS OF CRANK CHAMBER, SHEWING ALSO SYSTEM OF LUBRICATION OF MAIN AND CRANK PIN BEARINGS.

Fig. 8.

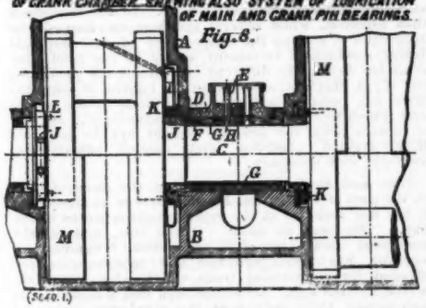



Fig. 8. LIST OF PARTS.

A. Cylinder and top chamber.
B. Soleplate.
C. Crankshaft.
D. Main gearing cover.
E. Main gearing cover, oil tubes.
F. Main gearing bushes.
G. Main gearing bushes, white metal.
H. Main gearing bushes, oil tubes.
I. Centrifugal oiler.
J. Airtight rings.
K. Airtight rings, springs.
L. Airtight rings, driving pins.
M. Balance weights.

Fig. 9. LUBRICATING OIL COLLECTOR FOR GUDGEON PIN.

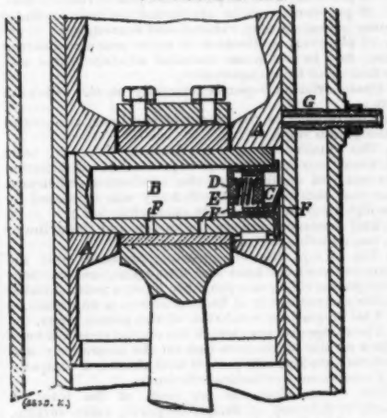



Fig. 9. LIST OF PARTS.

A. Piston.
B. Gudgeon pin.
C. Oil collector.
D. Oil collector casing.
E. Oil collector spring.
F. Oil holes.
G. Oil tube from lubricator.

heavier nature, which have been more readily procurable within the last few years, thus extending greatly the field of application. This movement has been largely responsible for many attendant improvements such as increasing the compression pressure.

The present stage of development of the semi-Diesel engine permits it to use most of the heavy fuel oils ranging from 0·8 to 0·9 in specific gravity and with flash points from 130 deg. to 250 deg. F. Perhaps the most frequently used oils are "Solar" and "Shale," but paraffin at the one end of the scale and Texas at the other may be said to be quite suitable without special adjustments or contrivances. Very thick oils such as "Mexican" for example, may be used, but require preheating to facilitate pumping, and periodical runs on lighter oils are desirable in such case in order to keep the pipes clear, the pistons clean, and the piston rings free in their grooves. With regard to sulphur, the semi-Diesel is no more sensitive than the Diesel engine. Experiments are being carried out at the present time in order to permit of the use of tar oil.

A note should be made in connection with the subject of burning heavy fuel oils with semi-Diesel engines, that this engine being a "solid" injection engine does not run with such a clean exhaust as is customary with air-injection engines, and the amount of overhauling required for cleaning of piston rings, &c., is on that account greater, and, of course, is increased with the heavier oils as compared with shale oil and such lighter oils. The user must, therefore, balance the gain of cheap and readily-obtained fuels with the extra overhauling which may on that account be required, taking into account the size of the engine as to whether the parts to be handled are of convenient size and weight.

*Lubrication.*—On the subject of lubrication, Fig. 8 shows the means provided for the main and the crank-pin bearings, and Fig. 9 illustrates a satisfactory device for the lubrication of the connecting-rod top end bearing, whereby the oil is collected from the cylinder walls and conveyed to this bearing. The lubrication of the cylinder walls is carried out in exactly the same manner as is customary with Diesel engines, a special lead being provided for the top-end bearing. Forced lubrication to the main, crank-pin and top end bearings cannot be used with semi-Diesel engines, so long as crank-case scavenging is utilised in order to avoid excessive impregnation of the crank chamber air with lubricating oil.

The qualities of lubricating oil desirable for semi-Diesel engines differ in no way from those required by the Diesel engine, and, with careful design of the airtight rings shown in Fig. 8, and good fitting piston rings, the consumption of lubricating oil compares favourably with the figure for two-cycle Diesel engines, and is in the neighbourhood of 0·02 lb. per brake horse-power per hour.

*Starting.*—Semi-Diesel engines are started by means of compressed air. Due to the low compression pressure, a comparatively low pressure of starting air is sufficient to ensure reliable starting. The minimum pressure at which the engine will start is from 80 lb. to 100 lb. per square inch, and the starting air is generally stored at 200 lb. per square inch, which, with a suitable volume of storage, gives the requisite number of starts, or a margin for contingencies. Prior to starting the hot bulb is brought to a sufficient temperature to ignite the fuel, which is accomplished by means of a blow lamp in from 10 minutes to 15 minutes. If the engine is provided with special starting plugs of nickel steel screwed in the hot bulb, very much less time is required. These special plugs quickly attain the necessary temperature for ignition. One impulse is generally sufficient to start the engine, so that operating gear for the starting air valves, other than a hand lever, is not customarily fitted with land engines, excepting occasionally in the case of four-cylinder engines. For the compression of starting air a separate hand or power-driven compressor can be installed. The practice with semi-Diesel engines is, during each working stroke to tap off a portion of the working gases through a combined non-return and screw-down valve on the main cylinder, and to pass them to the starting reservoir or reservoirs until such time as any reduction of contents of these reservoirs has been made good.

For multi-cylinder engines which require to start against a load, as for instance those driving pumps or propellers, the same mechanism can well be fitted as with the Diesel engine, the starting air valves being operated either from a main camshaft or through a distributing box, with a secondary camshaft driven from the crankshaft. The quantity of air storage requisite for starting is generally considerably less than is required by Diesel engines, since the hot bulbs have, of necessity, been heated prior to turning the engine, and one revolution on compressed air is sufficient to start the engine.

The quality of reversibility, which is almost exclusively required for marine engines, presents few difficulties where 2-cycle semi-Diesel engines are concerned, and some notes in regard to this subject are given in Appendix II.

*Reliability and Regularity in Operation.*—As would be expected from the extreme simplicity of this prime mover, its reliability and regularity in operation are of a high order. Due to the necessity of restricting the quantity and minimising the pressure of lubricating oil, as already dealt with under the heading of "Lubrication," earlier designs were subject to bearing troubles attributable to the failure of the lubricating system. With modern designs ample bearing surfaces and carefully-designed means for the provision of the necessarily restricted quantity of lubricating oil, these defects have been entirely eliminated.

The system for fuel injection due to the adoption of "solid" or "mechanical" injection is considerably simplified in comparison with air injection engines.

Faulty circulation of cooling water and unsatisfactory designs of castings—more particularly those for the cylinder head and hot bulb—have been the cause of a certain amount of trouble with cracked heads and so forth; but modern designs have practically overcome this earlier source of unreliability.

*Conclusion.*—The rapid extension within the last few years not only of the field of application, but also of the size of engine and power developed per cylinder with semi-Diesel engines, foreshadows considerable developments in the near future. In these developments the influence of the design and practice of the pure Diesel engine will probably play a considerable part, and it may be expected that the lines of design of the Diesel and semi-Diesel engines will become more closely merged.

Practical difficulties would seem almost to confine the semi-Diesel engine to the two-stroke cycle. Developments towards improving the efficiency of scavenging may well be expected. In the United States of America semi-Diesel engines with separate scavenging pumps, crossheads, and so with forced lubrication, are already making their appearance.

The mean effective pressures developed by the semi-Diesel engine under conditions of continuous running are considerably less than those associated with the Diesel engine, due primarily to the questions of scavenging and compression already fully discussed. It is not expected that other than a slight increase in mean effective pressures can be looked for in the near future, since the simplicity of the semi-Diesel engine and its relatively low compression pressure will probably be substantially retained. The low mean effective pressure in reducing heat stresses and temperature conditions within the cylinder makes for reliability in operation.

The vexed question of "solid" injection of the fuel becomes a simpler issue when associated with surface ignition. All considerations in the design of the fuel pump operating and controlling gear, and the injection means for semi-Diesel engines, have in the past been subservient to that of simplicity. With a demand for the same degree of flexibility, and a capacity to burn as wide a range of fuels, without recourse to the water drip, as obtains with the Diesel engine, considerable improvements after the war can confidently be anticipated.

## APPENDIX I.

### Mechanical Efficiency of Internal-Combustion Engines.

The following notes have special reference to internal-combustion engines of the trunk piston type; but apply equally, with slight modifications, for crosshead engines.

Mechanical efficiency (the ratio between brake horse-power and indicated horse-power) is affected by the number of auxiliaries which are driven by the main engine.

1. Except in so far as auxiliaries are concerned, the difference between the indicated horse-power and the brake horse-power can be apportioned as follows:—

(*a*) 50 per cent. is due to piston and piston-ring friction.

(*b*) 28 per cent. can be attributed to main cylinder pumping losses, suction, exhaust and scavenging.

(*c*) 22 per cent. is allocated to valve gear and bearing friction, &c., in which are included windage losses and other factors of little importance.

2. Piston friction depends primarily on the following factors:—

(*a*) The quality of the metal of the liner, the piston and the piston rings.

(*b*) The quality of the lubrication. (Certain tests which have been carried out go to prove that a diminution in viscosity of oil increases the mechanical efficiency. In one case the mechanical efficiency was increased by water injection into the combustion chamber.)

(*c*) The clearance between the piston and the cylinder walls, has an influence on efficiency.

(*d*) The m.e.p. the compression pressure, and the pressure between the liner and the piston, and the liner and the piston rings, can probably have a most suitable value for the reduction of friction loss to a minimum.

(*e*) The fit and the condition of the piston rings.

(*f*) The temperature at which the engine runs will have an effect on the lubrication and on the clearance; and it has been substantially proved that there is a temperature of maximum mechanical efficiency.

3. The suction loss, 28 per cent. of the total, is primarily a function of design of ports, valve setting, piston speed and gas speeds.

4. The valve gear and the bearings, 22 per cent. of the total loss, will depend on the design of the engine, the alignment, the efficiency of the lubrication.

In addition to the foregoing, there are records of mechanical efficiency being reduced by increased weight of flywheel.

Generally, mechanical efficiency is adversely affected by increased speed and reduced m.e.p.; and decreased by mal-alignment, &c.

The mechanical efficiency may be affected by the form of the combustion chamber which may produce undue distortion of the piston under working conditions, although this is probably extremely slight; distortion of the piston being more due rather to the condition of the gudgeon pin bearing than to any other cause.

The mechanical efficiency, assuming a constant m.e.p., is practically unaffected by the size of the engine.

In connection with the above, a large number of records of tests of engines have been investigated from Guldner, Supino, D. Clerk, &c.

## APPENDIX II.

### Reversibility.

Reversibility need only be discussed in relation to two-cycle semi-Diesel engines, since those working on the four-cycle principle have not, as yet, been made directly reversible. The compression of the scavenging air in the crank chamber fitted with automatic valves, and the operations of scavenging and exhaust within the working cylinder are directly reversible (see Fig. 2).

The only problem remaining is that of the timing of the injection of the fuel for the reverse direction of rotation. If the end of the delivery stroke of the fuel pump coincides with the top dead centre of the main piston, no alteration in timing for fuel injection is required for astern running. This condition is satisfied in most of the multi-cylinder reversible semi-Diesel engines. However, should the timing of the fuel pump be such that the end of the delivery stroke does not coincide with the top dead centre, then operating gears are necessary for the fuel pumps—one for ahead and one for astern—in an exactly similar manner to the arrangements adopted for Diesel engine cylinder head fuel injection valves with reversible marine engines.

The method adopted for changing the engine from the ahead direction of rotation to astern, may be:—

(*a*) By means of a pre-injection and ignition of fuel.

(*b*) Pre-injection of starting air.

(*c*) Stopping the engine, reversing the driving mechanism of the starting air valves and possibly of the fuel pumps as well, and starting up the engine in the astern direction.

With (*a*) and (*b*) the fuel pump is timed so that the point of delivery coincides approximately with the top dead centre of the main piston, and arrangements are made, that when the fuel is cut off, the engine is declutched, the speed falls to a predetermined minimum and an injection of fuel or starting air is effected by the governor on the up stroke of the piston, so driving it in the reversed direction. Method (*c*) is only applicable to four-cylinder engines, since engines with a lesser number of cylinders cannot be started from any position of the cranks at which the engine may have stopped. Although a clutch is generally fitted, it is not necessary for method (*c*). For a full description of method (*c*), see Engineering for August 24, 1917.

## NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

*Heat in Steel Work.*—In a paper before the Sheffield Society of Metallurgists and Metallurgical Chemists this week, Professor Carpenter dealt in an interesting manner with the question of temperature of steel during the mechanical operations thereon, urging that if the best was to be got out of any particular steel, investigation was necessary as to the degree of temperature, or range of temperature at which mechanical work was done upon it, more particularly the temperature of the finishing work. To obtain the best results it undoubtedly was necessary to take into account not only the condition under which the ingot was cast, the chemical composition of the steel and the method in which the work was applied, but also the temperature at which the work had been done. In the discussion that followed, while several speakers emphasised the difficulties of reading the temperature of steel materials during mechanical treatment, owing to the brief time available during the different operations, the president, Dr. W. H. Hatfield, stated that the control of temperatures was possible, and was being done in the works with which he was concerned, with advantage. He saw no reason why the practice should not be general. Highly-trained observers and careful calculations, however, were necessary.

*Iron and Steel.*—Notwithstanding the peace feelers on the part of the Central Powers there is no slackening in the war pressure at the great munition works in the city. "Business as usual" is the rule, and all the armament shops are full of orders. Organisation, however, has been perfected and opportunities are afforded for commercial trade which were impossible twelve months ago. Local furnaces find a difficulty in maintaining their output at the maximum owing to labour difficulties, and the shortage of the coal supply. The export trade continues to improve slowly but steadily. Permits to export crucible steel tools, &c., are much more readily granted, and business with the United States, South America and South Africa is increasing. The Board of Trade returns, however, still show a marked decline when compared with recent years. The drop is especially heavy in manufactured steel, including the various kinds of crucible steel. During the nine months this has only reached 121,346 tons, compared with 500,000 tons two years ago. Last month the figures were only 8,900 tons, compared with 36,617 tons in September of 1917. This is to some extent accounted for by the fact that France and Italy are now making a good deal of the steel which they formerly imported from Sheffield. Engineering concerns generally are full of work and have excellent post-war prospects. Many have orders in suspension which will keep them busy for a long time to come. The exhaustion of steel and steel goods throughout the world gives promise of a period of full work in replenishment, though there are doubts whether consumers will be prepared to order largely at the huge inflated prices which must continue for a lengthy period ere anything like a genuine standard can be ascertained. Buying, for a period, will in all probability be of a hand-to-mouth character, though, as goods of every description will be wanted in enormous quantities, there is no fear of any period of slackness.

*South Yorkshire Coal Trade.*—No change of importance is noted in the coal trade of the district. Steam fuels of every description continue in great request. Full supplies are going to munition works, but many establishments are finding that they are having to fall back on reserves to maintain their maximum output.

Houses not directly engaged on war work are complaining of shortage, and in some instances are unable to work full time. The demand for slacks is strong with prices unchanged. Blast-furnace coke is in active request, and works find a difficulty in meeting their requirements. In house coal the market is quiet. The output, though improving, not having increased sufficiently to have any agreeable effect. London is taking a heavy tonnage. Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

## NOTES FROM THE NORTH.

GLASGOW, Wednesday.

*Scotch Steel Trade.*—Contrary, perhaps, to expectation the Peace Notes have had little effect upon the steel-making industry, and certain it is that so long as the war continues as at present the production of all grades of steel must go on with unceasing activity. The bulk of the present output goes direct to home consumption, the demands from the shipyards especially being of a most pressing character, plates and sections being in constant request. Various overseas' customers are also clamouring loudly for plates for delivery ahead, but meantime steel-makers have sufficient work of an urgent nature on hand so that they are shelving these inquiries until a more convenient season. Finished steel for the engineering works is another heavy item. Manufacturers are still much perplexed over the fuel problem which in no way gets easier, but rather more difficult as winter approaches, although, doubtless, the household rationing scheme should help towards a olution.

*Malleable Iron Trade.*—Ceaseless activity continues in the malleable iron trade with a constant pressure for delivery of material urgently required for work of national importance. In this category must be reckoned sections for shipbuilding yards and locomotive works; bolt and nut iron; light rails, &c.; all wanted in such a hurry that every available mill is kept running to its utmost capacity. As in kindred industries the shortage of the coal supplies causes considerable anxiety, while the accumulation of arrears is unavoidable.

*Scotch Pig-Iron Trade.*—So long as present conditions endure there seems little likelihood of any decrease in the demand for pig-iron and, as at the moment, the hand-to-mouth business will probably hold for some considerable time to come. Under Government control, all grades are moving quickly into consumption, hematite being in constant request at the steel works. The restrictions on export are all to the advantage of the home consumer, and thus the shortage of certain brands is not so keenly felt as would otherwise be the case. Prices are unchanged.

*Effects of Standardisation.*—An interesting feature resulting from the standardisation of ship machinery is at present being demonstrated in Messrs. Harland and Wolff's engineering works in Greenock, where, in order to speed-up the output of mercantile shipping, five standard vessels built in other yards are being engined. This is the first occasion upon which Messrs. Harland and Wolff have undertaken such a task, the advantages of which, under existing circumstances, are undoubtedly, manifold. Three of the vessels were built at Dumbarton, and the other two at Port Glasgow.

## NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

*The Cleveland Iron Trade.*—Demand for pig-iron, and particularly foundry quality, is keen, and delivery is fairly heavy. Means of distribution, however, are inadequate, and makers are supplying customers as equitably as circumstances permit. The truck situation still leaves much to be desired. Whilst some works are fairly well placed in this respect, others continue to complain of short supplies. On the other hand steamer tonnage is coming forward well, and this month's shipments, both to coastwise customers and to buyers abroad, promise to be considerably above the clearances for September. A few cargoes are permitted to be loaded for neutrals from time to time. In the home trade further sales of Cleveland forge iron, both on early and forward account, are reported. Supply is plentiful, and there are good inquiries for as far ahead as the early part of next year. Some of the blast-furnaces which had not been working too well are stated to be running better. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; and for shipment to France and Italy, No. 3 and the lower qualities are 122*s.* 9*d.* and No. 1 is 127*s.* 9*d.*

*Hematite Iron.*—Better account is given of the East Coast hematite trade, and indeed conditions are now regarded as satisfactory. Essential home needs are receiving adequate attention, and exports are on a substantial scale, loadings for Italy being exceptionally heavy. Mixed Nos. are 122*s.* 6*d.* for home use, and 147*s.* 6*d.* for shipment to France and Italy.

*Manufactured Iron and Steel.*—The various branches of the finished iron and steel industries are characterised by great firmness and very considerable activity. There is no relaxation in pressure for delivery, and the huge production promptly passes into consumption. A large proportion of the output consists of the various descriptions needed for shipbuilding, but production of constructional material is also heavy, and light sheets are being extensively manufactured. For home consumption the following are among the principal market quotations:—Common iron bars, 14*l.* 15*s.*; best bars, 15*l.* 15*s.*; best best bars, 16*l.* 15*s.*; best best best bars, 17*l.* 15*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; iron ship rivets, 21*l.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel strip, 17*l.* 10*s.*; steel hoops, 18*l.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*—all f.o.t. at makers' works. Export prices are not fixed, but they are approximately 40*s.* above home quotations.

*Coke.*—Demand for coke is large, and generally supply is scarce, but deliveries to local blast furnaces are now made with gratifying regularity. Average furnace kind is 33*s.* at the ovens, and low phosphorus quality 35*s.* 6*d.* at the ovens.

## NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

*The Local Markets.*—The position on the local markets is causing some anxiety at the present moment. Production is fairly well maintained, but the great difficulty is in regard to transport. Shipments are fairly well, and the inland demand is great—much in excess of the supply, but unless there is an appreciable improvement in the transport arrangements soon, there are indications that collieries may have to suffer from temporary stoppages. Admiralty collieries as well as those producing the best grades of large coal, are well provided for, but the others are not so fortunately situated. Any stoppage at the present day would be exceedingly regrettable in view of the shortage, and representations are being made to the authorities with the view of seeing what can be done to bring about an amelioration of the position.

*Newport.*—The inland demand for Monmouthshire coals exceeds the supplies, but smalls are on the easy side, though bunkers are well taken up. There have been quite heavy shipments this week, and, fortunately, there has been an absence of labour troubles, both with the Eastern and Western Valleys, and production is therefore nearly up to the average in normal times.

*Surface Workers Eight-Hours Day.*—The demand of the surface workmen at the collieries—mainly those in the mechanical departments—is being pressed forward by the men's leaders, and something like a climax will be reached in the course of a week or so. However inopportune the demand for a curtailment of hours may be, it seems evident that the men are bent upon securing a change, and the view is felt that rather than precipitate a crisis it would be just as well for the owners to make arrangements at once for the establishment of an eight-hours day all round.

RETURNS AS TO RUBBER.—The Minister of Munitions has issued an Order requiring a return to be made on or before November 7 of all raw rubber and all waste and reclaimed rubber in the United Kingdom by all persons who, on October 31, held or controlled stocks exceeding 1 ton. The return must be made to the Controller of Rubber, Ministry of Munitions, 1, Grosvenor-place, London, S.W. 1.

THE BRITISH GAUGE MANUFACTURERS' ASSOCIATION, LIMITED.—This association was registered on September 17, 1918. Its objects are to promote and protect the gauge manufacturing industry of Great Britain. It is recognised by Government Departments, and amongst these is the Ministry of Reconstruction. Further information and particulars can be obtained from the Secretary, at 44, Caxton House, Westminster.

FORGINGS AND CASTINGS ORDER.—The Minister of Munitions has issued an Order dated the 18th inst., providing that producers of ferrous forgings, drop-forgings or castings shall furnish such particulars as are required of output, plant and workpeople employed, and of orders and contracts, to the Controller of Forgings and Castings, Ministry of Munitions, 8, Northumberland Avenue, W.C. 2.

PULVERISED COAL SYSTEMS IN AMERICA.—Mr. Leonard C. Harvey, Red House, Malden, Surrey, has returned from the United States after having carried out for the Director of Fuel Research a full investigation into the progress made in recent years in the application of pulverised coal for metallurgical and general industrial purposes, for steam raising in land and marine boilers, and in locomotives on railways. The purpose of the Director of Fuel Research in accepting Mr. Harvey's offer to make this investigation was that the most recent information on the subject of pulverised fuel should be available to all who are interested in the more scientific use of fuel. In order that effect may be given to this intention, the information and data collected by Mr. Harvey, together with descriptions of numerous installations inspected and statements as to the actual experiences of the owners of these installations are now being collated in the form of a report. This report will be issued as a Government publication by the Department of Scientific and Industrial Research at an early date. Important developments have taken place in America in the utilisation in pulverised form of low-grade coals of high ash contents, and it is hoped that similar developments will follow the adoption of the system in this country. It is possible that in this way considerable quantities of material which is at present regarded as waste at the coal mines may ultimately be made available as fuel, and thus supplement the restricted supplies of coal.

## NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS: MANCHESTER MEETING.—Friday, October 25, at 7 p.m., at the Engineer's Club, Manchester, when the following papers will again be read, in abstract, and discussed:—"A Law Governing the Resistances to Penetration of Metals when Tested by Impact," and "A New Hardness Scale in Energy Units," by Professor C. A. Edwards, D.Sc., and Mr. F. W. Willis, B.Sc., Manchester; "The Value of the Indentation Method in the Determination of Hardness," by Mr. R. G. C. Batson, of the National Physical Laboratory, Associate Member; "The Ludwik Hardness Test," by Mr. W. Cawthorne Unwin, LL.D., F.R.S., past-president.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, October 25, at 7.30 p.m., at 39, Victoria-street, Westminster, a paper on "Cooling Towers" will be read by Mr. J. Elliott.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS (INCORPORATED).—Friday, October 25, the thirty-fifth annual general meeting will be held in the Lecture Theatre of the Literary and Philosophical Society, Westgate-road, Newcastle-on-Tyne, and an Inaugural Address will be delivered by the president. The chair will be taken at 7.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS.—Saturday Evening, October 26, when a paper entitled "Fuel Oil and its Applications" will be read by Mr. A. F. Baillie, London. The paper will be delivered in the form of a Lecture and will be illustrated by lantern slides. The chair will be taken at 6.30 p.m.

THE JUNIOR INSTITUTION OF ENGINEERS; NORTH-EASTERN SECTION.—Tuesday, October 29, at 7.15 p.m., at the Mining Institute, Neville-street, Newcastle. Paper on "Coal and Ash Handling Plants," by Mr. N. Thornton.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS, LONDON (INCORPORATED).—(Leeds centre): Tuesday, October 29, at 7 p.m., at the Philosophical Hall, Leeds; paper by Mr. W. Paterson on "The District Supervision of the Locomotive Department of a British Railway." (London): Saturday, November 2, at 2.30 p.m., at Caxton Hall; paper by Mr. H. Holcroft on "Three-Cylinder Locomotives."

SCALES AND WEIGHING MACHINES INDUSTRY.—The attention of scale and weighing machine manufacturers is drawn to the concession which has been granted to the trade by the Priority Department of the Ministry of Munitions for the supply of metals required by the whole trade of the United Kingdom of manufacturers and repairers of scales and weighing machines for industrial purposes for home trade. The metals may be used for repairs and maintenance of weighing apparatus of all capacities, but, for new machines to replace those beyond repair, only those which do not exceed a capacity of 5¼ cwt. or a total weight (material) of 4¾ cwt., can be supplied. Under this new rationing scheme no new weighing instrument may be manufactured, supplied or sold, having a capacity of more than 5¼ cwt., total weight 4¾ cwt., or exceeding the following values: 56-lb. capacity, maximum value 20*l.*; 5¼-cwt. capacity, maximum value 50*l.*—without a special permit granted by the Priority Department of the Ministry of Munitions. Messrs. Price, Waterhouse and Co., chartered accountants, 3, Frederick's-place, Old Jewry, E.C. 2, have been appointed the rationing authority and will deal with applications for the release of material and apportion to each manufacturer the quantities allocated to them. Full particulars can be obtained from the Secretary to the National Advisory Committee, 97, Cannon-street, London, E.C. 4.

THE CALEDON YARD, DUNDEE.—Since its foundation, in 1875, the Caledon Shipbuilding and Engineering Co., Limited, has been essentially a builder of liners, first-class passenger boats, fast coaster and cross-channel passenger and cargo vessels, and vessels for special trades, such as fruit and cattle carriers. The men and the plant were all specially organised with a view to these types of vessels, and when war broke out all had to be changed over. Men in every department had to turn to a different class of work, with different classes of material and designs. The company now has eight berths instead of five, and later will have ten. All berths have been enlarged for greater tonnage; the increase in the size alone of the berths is sufficient to increase the output by 50 per cent. For the year 1919, the company fully expects to deliver 13 standard ships and most probably 14. If the requirements for repairs decrease, the output should be 15 or 16 vessels, *i.e.*, one completed steamer every 22 working days. It is obvious that repair work must interfere with the output of new construction. But it is equally obvious that tonnage thus restored to service is equivalent to new tonnage, is more rapidly put in service, and avoids the congestion of docks, &c., by damaged vessels lying up awaiting repairs. In the Caledon Yard in one year the number of repair jobs totalled 361; 309 in the shipyard and 52 in the engine works—practically a ship a day. The same ships appear more than once in the list and frequently the repairs are of the most trivial description, very many costing only a few shillings. The highest repairs bill for one ship in this yard is £15,326, and the greatest number of men put on to repair at one time has been 926. The Caledon Yard now employs only some 120 to 130 women, but when a new canteen has been provided, more will be taken on. The women are employed as labourers, carpenters painters, blacksmiths, &c., they are admirable workers and give no trouble. They excel as labourers and carpenters.

# SEMI-DIESEL OIL ENGINES.

(*For Description, see page* 461.)

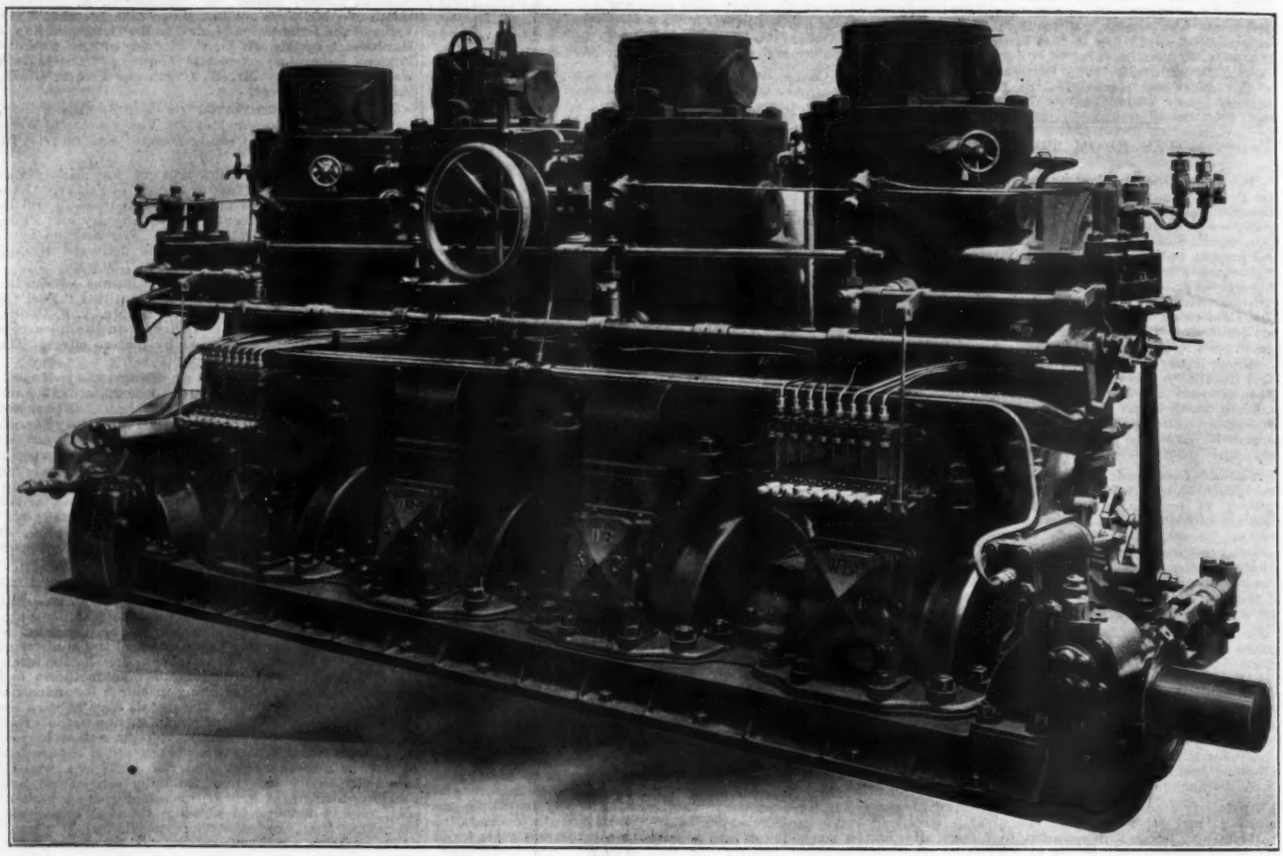


Fig. 10. Four-Cylinder Semi-Diesel Engine, by Messrs. William Beardmore and Co., Limited, Glasgow.

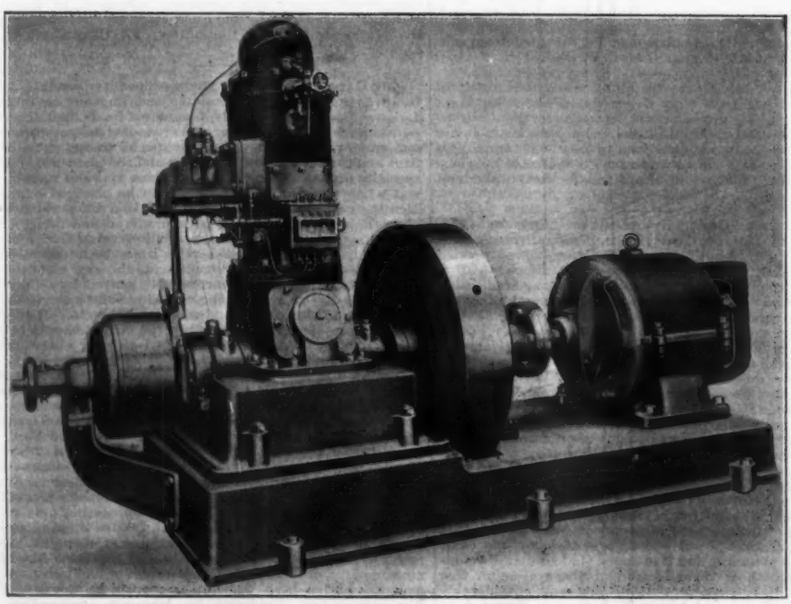


Fig. 11. Single Cylinder Semi-Diesel Engine by Messrs. Robey and Co., Limited, Lincoln.

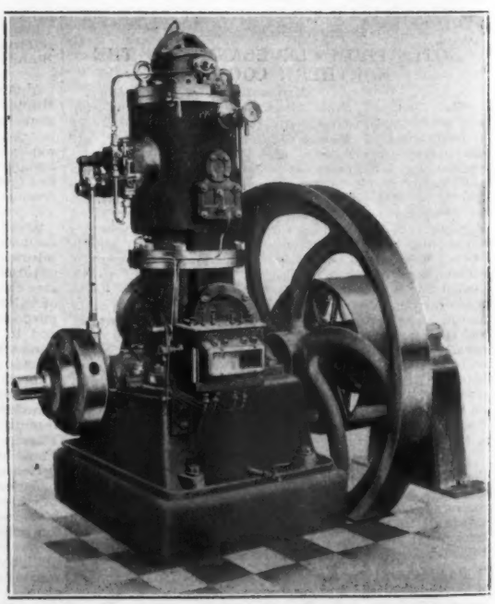


Fig. 12. Single Cylinder Semi-Diesel Engine by Messrs. Petters, Limited, Yeovil.

# REINFORCED CONCRETE RESERVOIRS AT MONTEVIDEO.

THE HON. R. C. PARSONS, M.A., M. INST. C.E., ENGINEER, LONDON.

(*For Description, see Page 453.*)

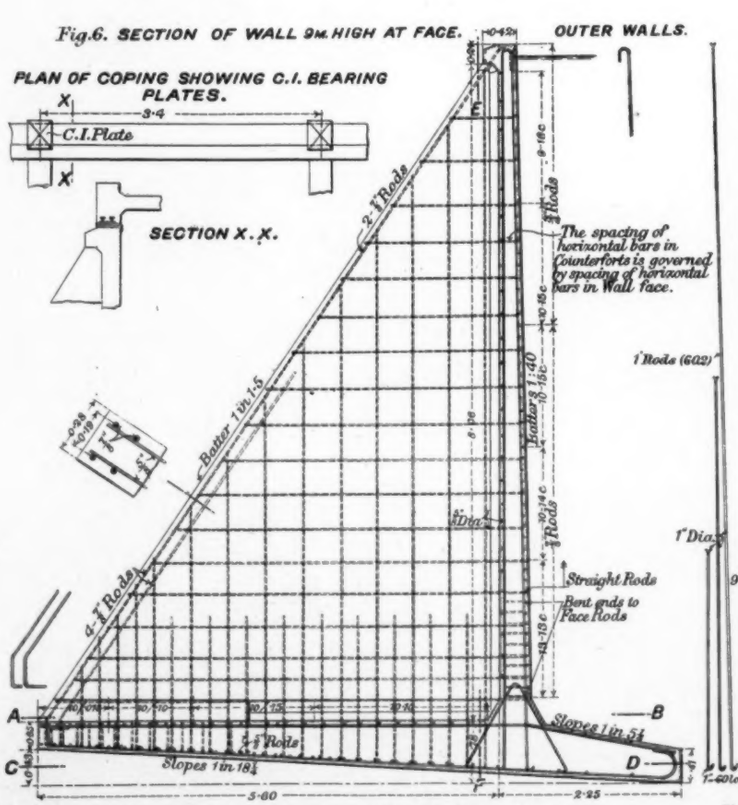
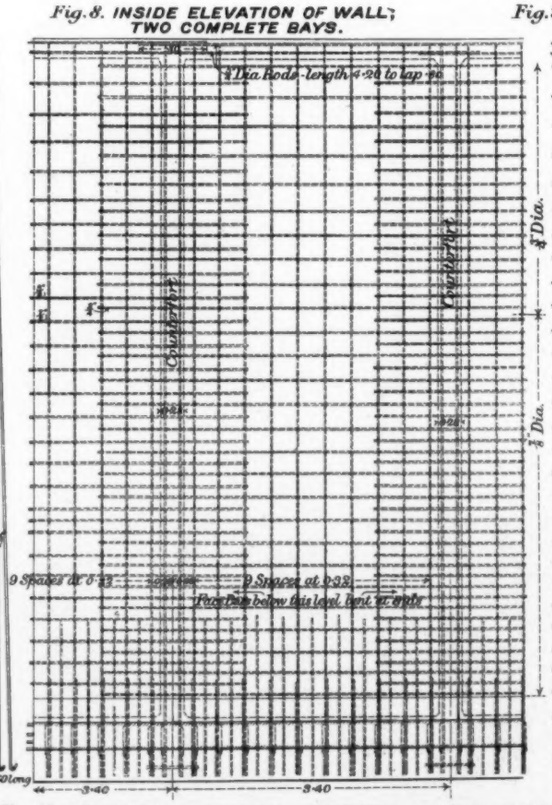
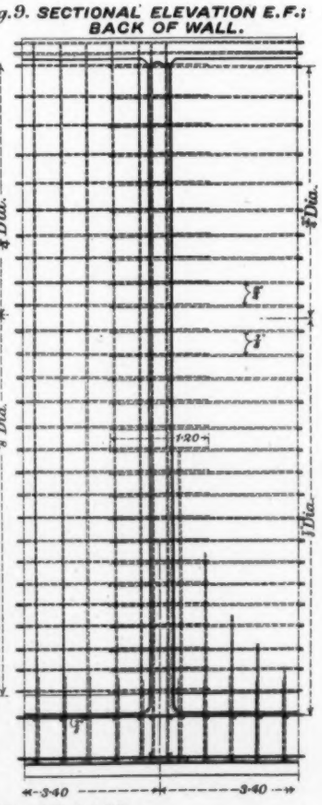
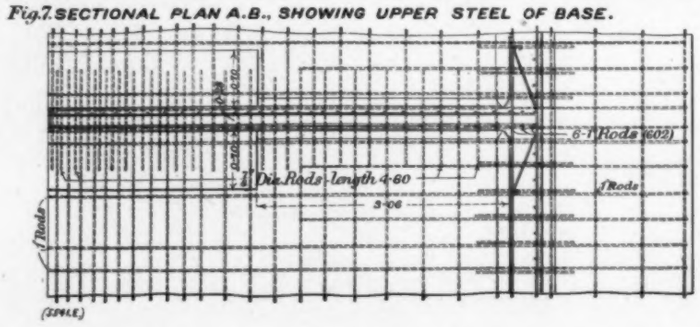


Fig.6. SECTION OF WALL 9m. HIGH AT FACE.
OUTER WALLS.
PLAN OF COPING SHOWING C.I. BEARING PLATES.
C.I. Plate
SECTION X.X.
The spacing of horizontal bars in Counterforts is governed by spacing of horizontal bars in Wall face.
Batter 1 in 1·5
Batter 1 in 40
Straight Rods
Bent ends to Face Rods
Slopes 1 in 54
Slopes 1 in 18
5·60
2·25



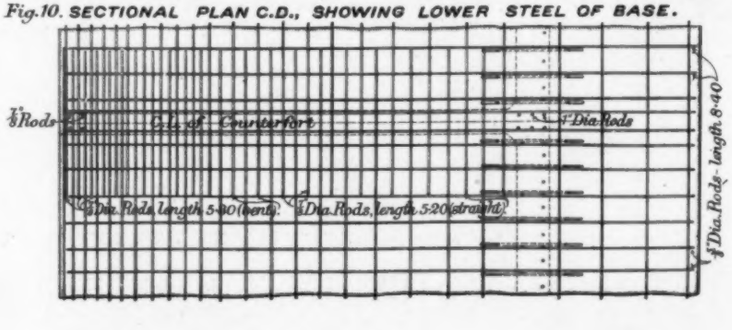



Fig.10. SECTIONAL PLAN C.D., SHOWING LOWER STEEL OF BASE.
1" Rods
C.L. of Counterfort
1" Dia. Rods
1" Dia. Rods length 5·40 (bent)
1" Dia. Rods length 5·20 (straight)
1" Dia. Rods - length 8·40

(*To face page 454.*)

# REINFORCED CONCRETE RESERVOIRS AT MONTEVIDEO.

THE HON. R. C. PARSONS, M.A., M. INST. C.E., ENGINEER, LONDON.

(*For Description, see Page 453.*)

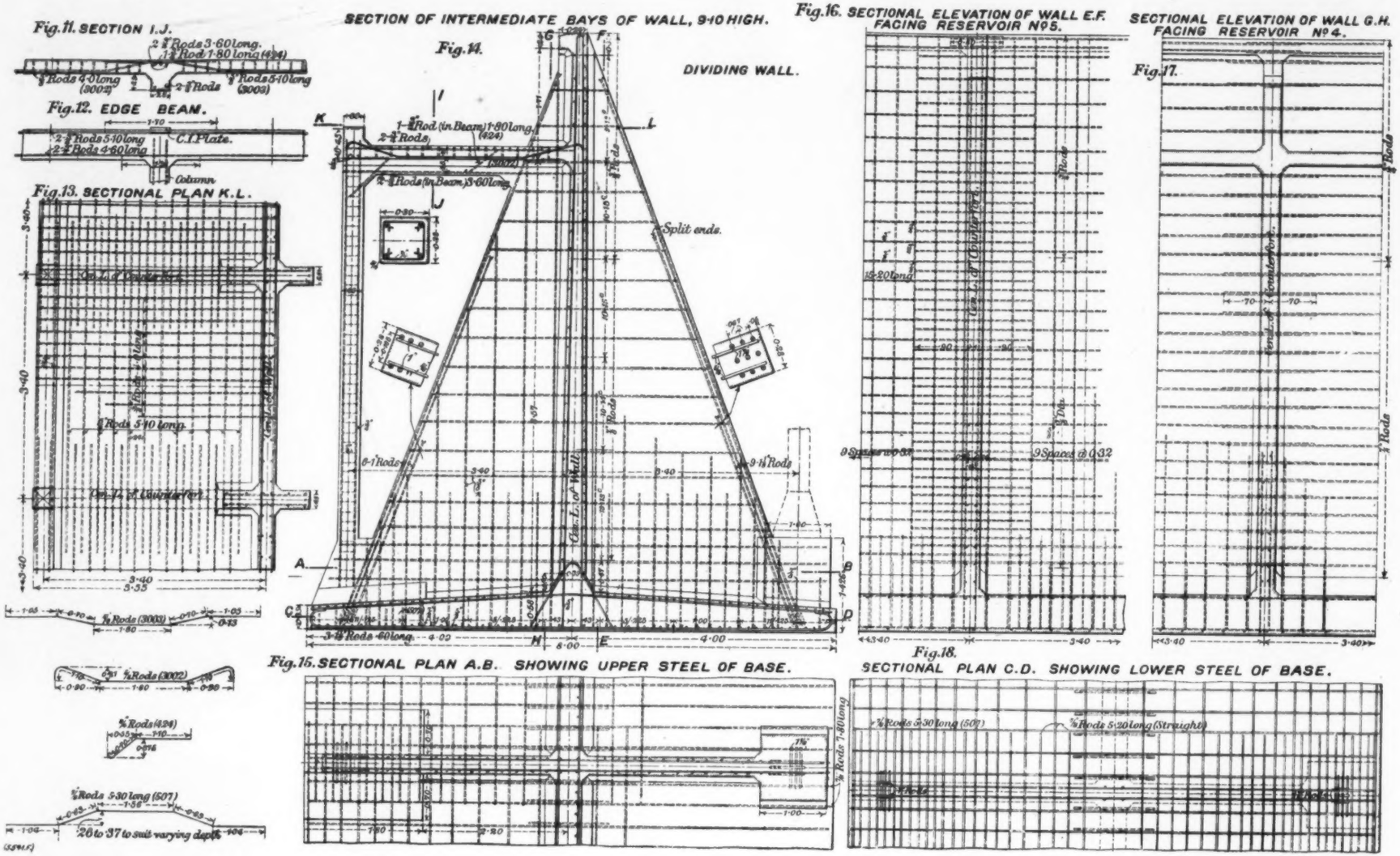


Fig.11. SECTION I.J.
Fig.12. EDGE BEAM.
Fig.13. SECTIONAL PLAN K.L.
SECTION OF INTERMEDIATE BAYS OF WALL, 9·10 HIGH.
Fig.14.
DIVIDING WALL.
Split ends.
Fig.16. SECTIONAL ELEVATION OF WALL E.F. FACING RESERVOIR No 5.
SECTIONAL ELEVATION OF WALL G.H. FACING RESERVOIR No 4.
Fig.17.
Fig.15. SECTIONAL PLAN A.B. SHOWING UPPER STEEL OF BASE.
Fig.18.
SECTIONAL PLAN C.D. SHOWING LOWER STEEL OF BASE.

# REINFORCED CONCRETE RESERVOIRS AT MONTEVIDEO.

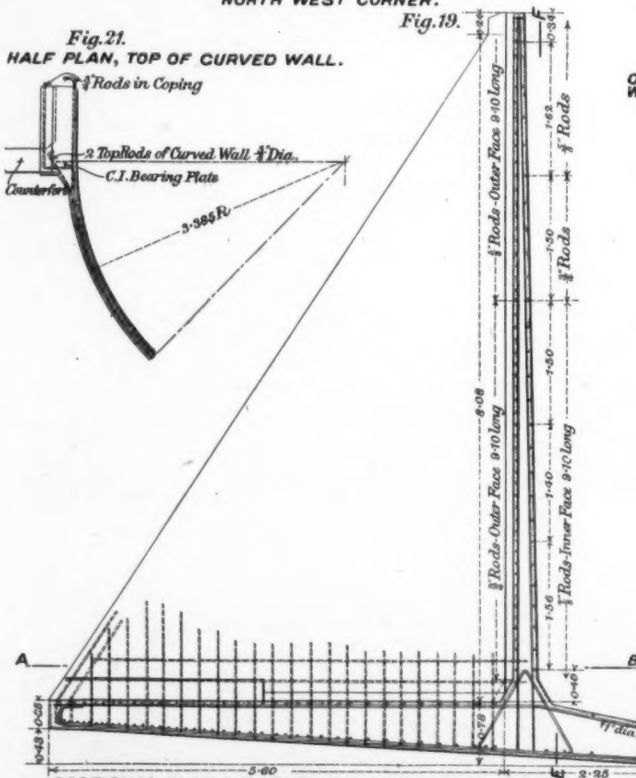
THE HON. R. C. PARSONS, M.A., M. INST. C.E., ENGINEER, LONDON.





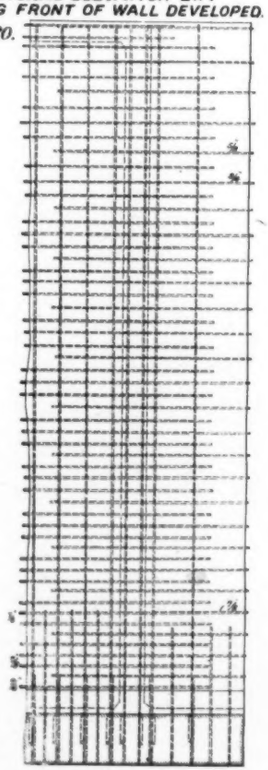
SECTION OF WALL, 9m. HIGH AT FACE, NORTH WEST CORNER.

Fig. 19.




SECTIONAL ELEVATION E.F. SHOWING FRONT OF WALL DEVELOPED.

Fig. 20.



OUTER WALLS.

Fig. 21.

HALF PLAN, TOP OF CURVED WALL.




SECTIONAL PLAN A.B. SHOWING UPPER STEEL OF BASE.

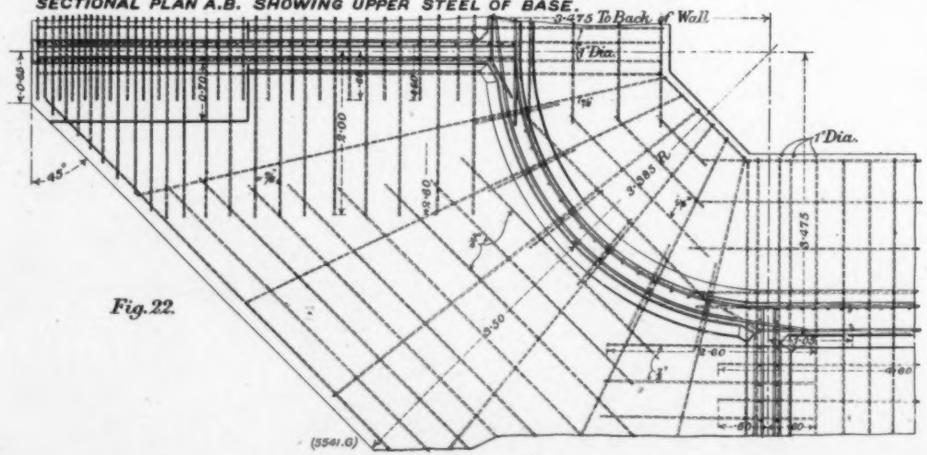


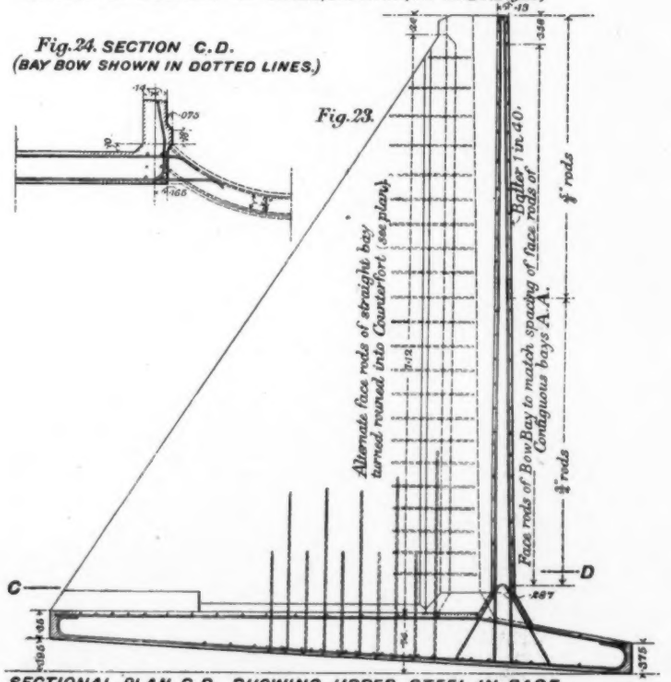

Fig. 22.

SECTION OF BOW BAY OF WALL, 8m. HIGH, AT A.B. (Fig. 25)

Fig. 24. SECTION C.D. (BAY BOW SHOWN IN DOTTED LINES.)

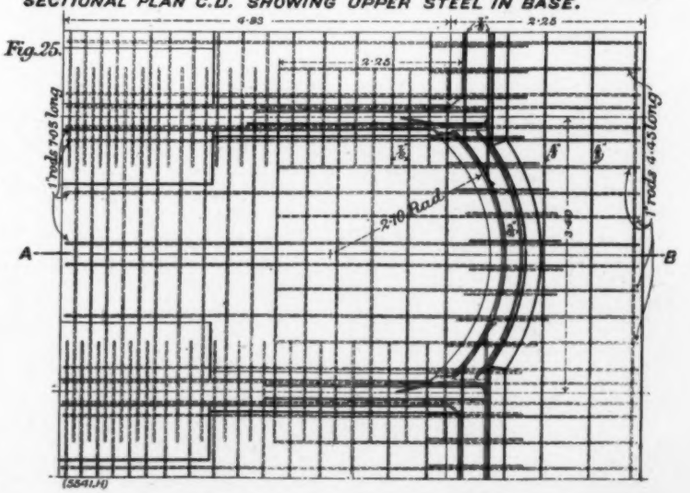


Fig. 23.


Alternate face rods of straight bay turned round into Counterfort (see plan).
Taper 1 in. 40.
Face rods of Bow Bay to match spacing of face rods of Contiguous bays A.A.
½" rods
½" rods
C
D

SECTIONAL PLAN C.D. SHOWING UPPER STEEL IN BASE.

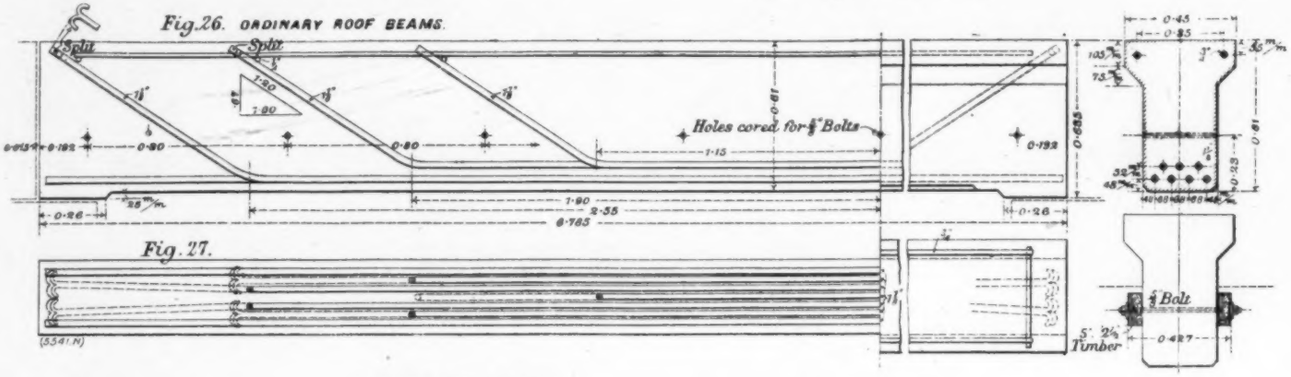
Fig. 25.

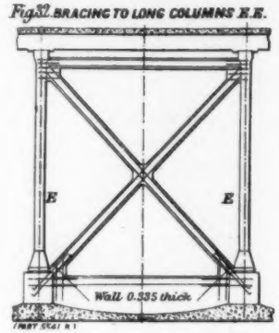


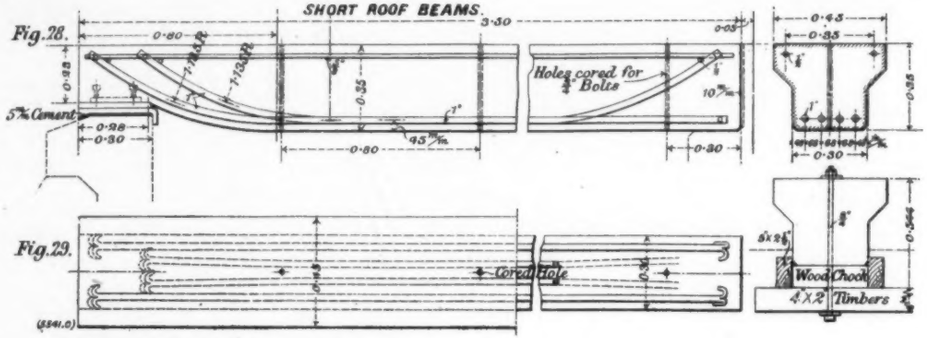
# REINFORCED CONCRETE RESERVOIRS AT MONTEVIDEO.

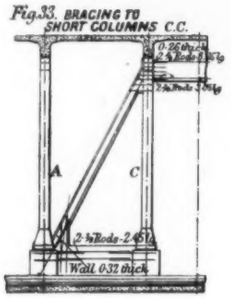
THE HON. R. C. PARSONS, M.A., M.INST.C.E., ENGINEER, LONDON.

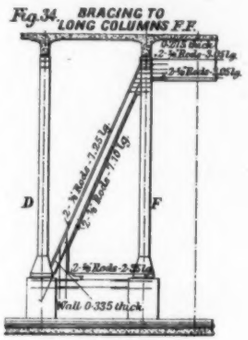
(*For Description, see Page* 453.)

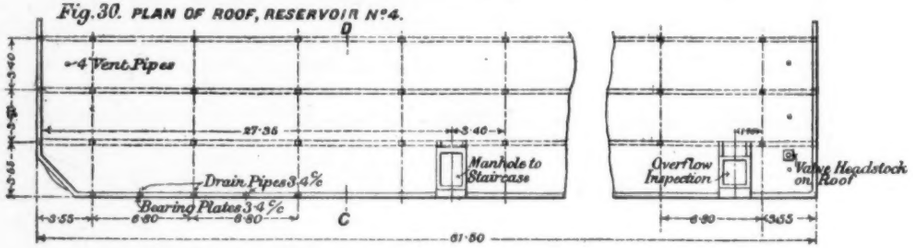


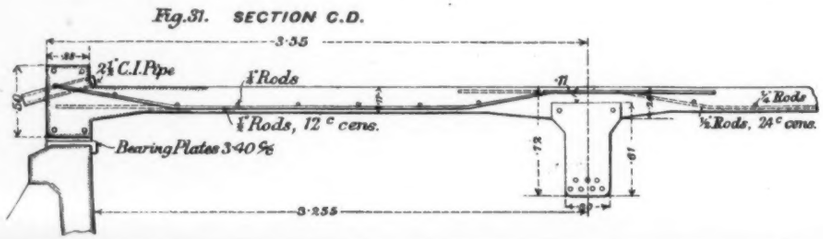



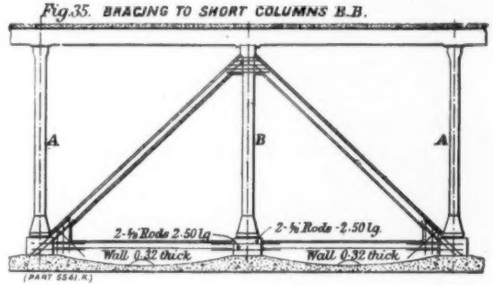

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**Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.**

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TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3663 and 8596 GERRARD.


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*With Four One-Page Plates of the REINFORCED CONCRETE RESERVOIRS AT MONTEVIDEO.*

## NOTICE.

**Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 9d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.**

### NOTICE TO NON-SUBSCRIBERS.

**In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.**

### NOTICES OF MEETINGS.

**Notices of Meetings to take place during the present and next week will be found on page 465.**

# ENGINEERING.

*FRIDAY, OCTOBER* 25, 1918.

## SCIENCE AND METALLURGY.

IN closing the discussion on one of the papers at the recent meeting of the Institute of Metals, the president, Professor Carpenter, expressed his "pleasure and surprise that a practical steel maker like Mr. Cosmo Johns had found time to study such purely scientific work as that of Moseley on atomic numbers." It was, he thought, a most significant sign of the times in which we lived, and the significance of the sign will be acknowledged and welcomed by everyone who is interested in the development of technical opinion in this country, and who has only too frequently had occasion to deplore the lack of co-ordination between the purely scientific and the industrial outlook.

Lack of co-ordination springs from a lack of common interests and it is not a difficult task to find the underlying causes for the lack of interest shown in technical matters by the average director and manager of industrial operations. A glance at the discussions on papers presented in past years before any of the British technical societies supply the evidence, in overwhelming bulk and monotony of phrase. And in passing, we would like to ask why the majority of the contributors to such discussions show such a love for the standardised phrase. It is inevitable, we suppose, that members should be "very much interested" in each "valuable addition" to our knowledge and "very much indebted" to the author for his "valuable contribution," but there is no reason why the choice of words in which the kindly thoughts are expressed should be so limited, or their form so stereotyped. We can only conclude when half a column of such factory-made remarks are adopted to do duty as a criticism of a technical paper, that the contributor is ignorant of the technical points involved. It is not necessary that contributors should be able to express themselves with the studied faultlessness of Robert Louis Stevenson's prose, nor is it even desirable that scientific criticism should be guided by literary imagination, but it is essential that every technical point raised be thoroughly understood.

Looking over such discussions for many years back one can estimate in a rough manner the state of technical knowledge of those engaged in industrial application, remembering at the same time that the conditions are most favourable, since those who take an active part in the proceedings of the societies are among the most advanced and progressive of their time. And the advance in the value of such discussions during recent years has been striking. Industrial men are now in many cases just as well equipped in the extent of their knowledge and in their breadth of outlook on matters of theoretical scientific interest as many of those whose profession it is to lead progress in new thought, while with the facts and problems of their everyday work before them they are not likely to stray far from the paths of practical utility in their inquiries.

Our future industrial managers must be technically trained. The old jibe that a university training bred nothing but unpractical theorists, and therefore incapable men from the industrial standpoint, has by now been completely discredited. If everyone had a technical training the man with the metaphysicist's type of mind might still be unpractical in the business of life, but the man of action would have an enhanced value, since grafted on to his energy and initiative he would have the ability to think clearly and the will to form reasoned conclusions.

The autumn Meetings of the Iron and Steel Institute and the Institute of Metals show the development of the modern spirit in a clear manner. They show how the metallurgical industries are becoming more scientific in their outlook and that they are benefiting in consequence is not less evident. The authors of papers are to a greater extent than ever before being drawn from amongst those whose daily work is concerned with one or other of the many phases of metal manufacture.

For many years it has been thought that the more hot work that steel received—that is the more deformation it received at high temperatures during the process of manufacture from the ingot to the finished job—the better the metal became, and although no evidence was ever put forward to support the contention, it was accepted by nearly everyone concerned as a fact based on long experience. Thus it was recognised and included in many specifications of certain classes of steel product, usually in the form of a minimum size for the ingot from which the specified job was to be made. M. Charpy set out to seek the evidence for the accepted view, however, and found, as often happens, that the view based on experience was only partially true. His paper on "The Influence of Hot Deformation on the Qualities of Steel," is an excellent example of the type of paper in which the results are achieved by a happy blend of technical skill and practical works knowledge. It is improbable that anyone realised before the enormous differences in the degree of hot work which was possible between closely and similarly situated areas in a plain bar forging. The lines of flow made evident by modern etching methods are very complicated, and it was found that when equi-distant lengths were marked off along the axis of the bar, in place of an average elongation of 4.8, the minimum might be as low as 2.37, and the maximum as high as 7.30. The prescription of a minimum size for the ingot does not ensure, therefore, that the minimum amount of work desirable is put on every part of the finished forging. Indeed, unless the finished job is very regular in shape it is most improbable that such is the case. As might be expected, it was found that the rolling operation gave the most uniform application of work throughout the mass, all lengths parallel to the axis of rolling getting equivalent amounts of hot work.

Whatever advantage was gained in the length direction after drawing down was lost in the cross direction so that it was easy for the amount of hot work to become excessive. The degree of hot work does not increase the tensile strength in any way after treatment but the ductility and the impact value are both very sensitive to its effects especially in the direction transverse to the deformation.

Though no reasons were assigned by M. Charpy, the cause of the directional effect of hot work on steel is largely connected with the presence of non-metallic impurities in the original ingot. With increased deformation these inclusions get drawn out into threads which though they do not greatly affect the ductility in the length direction have a bad effect on the cross ductility and the impact test. But since they are always present no matter how the steel is made, the best results will only be obtained when allowance is made for their presence during the metallurgical treatment of the steel.

These results are of importance not only to the metallurgist who is concerned with the physical properties of the material, but also to the machine designer because the essential factors of strength and ductility in a complicated section might not be compatible with the only method of manufacture possible. They also show that much forging work may increase the cost without conferring any

(To face page 455.)

benefit on the product, and that for high duty material the best results can be obtained by casting an ingot of such a size that the ratio of cross section of the ingot in the greatest cross sectional area of the finished job need not be greater than from 3 to 5. It is interesting to remember that some time ago (Engineering, Vol. 103, p. 271) Sir William Beardmore stated from his experience of large forgings that this ratio need not exceed 3 to obtain the benefits of hot work, a figure which has been confirmed by the quantitative measurements of M. Charpy. Small ingots are likely to come back into favour now in many works where the simplification in the handling of large outputs has led to a progressive increase in the size of ingots cast. We think that it will be a wise movement in many ways.

A new discovery of considerable theoretical importance has been brought before the Institute of Metals by Mr. Alkins through his study of the tensile properties of cold drawn copper wire. At a certain stage in the drawing of bronze wire it becomes brittle, but this brittleness can be removed by merely continuing the drawing of the wire a stage further and without any annealing operation. As a preliminary to the investigation of this peculiarity pure copper wire was examined for tensile strength after increasing amounts of cold work, and the important fact brought to light is that the increase in strength brought about by drawing is not continuous with the reduction of section but that there is a stage in the degree of reduction where the strength of the wire is practically constant.

The amorphous theory of Beilby has found general acceptance as an explanation of the hardening of metals by deformation, the amount of hardening being proportional to the amount of amorphous phase present and therefore to the amount of deformation. To show that the hardening is not proportional to the amount of amorphous phase as the theory postulates entails a revision of our views on this much disputed question, just as our ideas had seemingly become settled into a state of quiescent acceptance. We are afraid that it will require all the mental agility of the adherents of the amorphous theory to restore their favourite to confidence once more, and their efforts to do so will be looked forward to with piquant interest. The scrapping of views no longer in harmony with our knowledge is one of the chief aims of our technical societies and to this end the metallurgical societies are ably "carrying on."

## THE INACCURACY OF THE GAS METER.

While some people are complaining that they have to pay higher rates for poorer gas, and that the gas meters continue to register high although they try to restrict their gas consumption, the gas companies find that the unaccounted-for gas has actually risen during the war period, and that most meters of consumers register slow, and not fast. The admission of the fact that the gas meters, against the records of which there is practically no appeal, can go wrong, may afford a certain satisfaction to the complaining public. Both sides, however, would prefer to have meters upon which they can really rely, and when the unaccounted-for gas of one London company—a very big one, it is true, the Gas Light and Coke Company—amounts to the whole output of the gas works of Brighton, the matter calls for serious consideration. In 1917 the Gas Light and Coke Company appointed a committee to inquire into the subject of "Unaccounted-for Gas." This committee has not yet completed its researches. Mr. B. R. Parkinson was, however, able last Friday to bring a preliminary report before the Life of Gas Meters Research Committee of the Institution of Gas Engineers, and Mr. J. G. Taplay, chief analyst of the company mentioned, presented a report on the "Corrosion of Dry Gas Meters" on the same occasion. Both these reports, which were discussed together, are of considerable interest.

The unaccounted-for gas is not necessarily wasted gas. When 100,000 cub. ft. of gas pass through the station meters into the mains, and the records of all the consumers' meters only total up to 90,000 cub. ft., 10,000 cub. ft are unaccounted for. The first idea that occurs to one is probably that gas is lost by leakage in the mains and branches between the two kinds of meters. Mr. Stephen Lacey tested, in 1917, sections of the mains of the company—the Gas Light and Coke Company is meant in these lines unless otherwise stated—which were known to be leaky; he estimated the loss from the mains at $\frac{1}{2}$ per cent., and considering that the service pipes contribute less towards the leakage than the mains and their joints, he put the whole leakage at less than 1 per cent. of the make. Mr. Parkinson found, however, that the unaccounted-for gas amounted to 7 per cent. of the make in 1917, and that the fluctuations in leakage from mains did not run parallel with the unaccounted-for gas; on the contrary, the one figure was high when the other was low. Other factors were evidently at work. Mr. Parkinson first considered the "volume corrections" due to temperature and pressure fluctuations. The mean temperature of all the station meters—all wet meters—of the eight works of the company happens to be 60 deg. F., though the temperatures differ much; taking the mean air temperature at 49 deg., the temperature of consumers' meters—mostly dry meters—at 54 deg., he makes his correction for a temperature difference of 60 — 54 = 6 deg., equivalent to a shrinkage of gas volume between works and consumer of $1\frac{1}{2}$ per cent. Against that is the loss in pressure, 10 in. of water at the station, 4 in. at the consumer; this difference of 6 in. would cause an increase in the volume of $1\frac{1}{2}$ per cent., balancing the loss due to the temperature difference. The company correct their make to a standard of 60 deg. and 30-in. barometer plus 6 in. of water, leaving their consumption uncorrected; so calculated on the whole year, these corrections give a figure of unaccounted-for gas annually which averages $\frac{3}{4}$ per cent. (on the meter) too much. In his charts, exemplifying his studies of unaccounted-for gas during the last 10 years, Mr. Parkinson deducted this $\frac{3}{4}$ per cent. from the figures supplied to him. The whole correction is obviously crude. We do not say this to criticise Mr. Parkinson; the problem is exceedingly difficult, but it was rather surprising that the corrections, which may be an important factor, were not commented upon during the discussion.

For several years now, the unaccounted-for gas of the company has amounted to 7 per cent. of the make, as we stated. Deducting from the assumed make 1 per cent. for leakage, $\frac{3}{4}$ per cent. for corrections and $\frac{1}{4}$ per cent. for station meters fast, *i.e.*, deducting 2 per cent., there would remain 5 per cent. unaccounted for; the deficit was ascribed to slow registration by the consumers' meters; that, however, remained to be proved. If the data had all been uniform, a relationship would have been difficult to establish. But in 1915 the 7 per cent. dropped to $5\frac{1}{2}$ per cent., and simultaneously, it was ascertained, the consumers' meters showed an improvement in their tests on the bench and in the repairing shops through which about 10 per cent. of all the meters pass annually. Inquiring into the possible causes of this drop in the unaccounted-for gas and of the improved performance of the meters, Mr. Parkinson's attention was directed to the fact that, owing to the shortage of coal more oil gas was used for carburetting water gas in 1915 than before. This oil, the charts suggested, was beneficial to the operation of the meters. Since the war the gas had, however, more and more been stripped of benzol, and this scrubbing had unintentionally also removed from the gas the heavier lubricating hydrocarbons which keep the leather of the valves in good condition. The thus stripped "dry" gas seemed to have corroded the dry gas meters of the consumers, which registered slow; only 3 per cent. of these meters are of the wet type, whilst wet meters predominate in Birmingham, Sheffield and in the north. The analytical researches by Mr. Taplay fully supported these views; some features of this investigation call for detailed consideration; for the present we keep to the main issue.

It was understood, and it is supported by the recent work, that valve leathers, dressed in the ordinary practice with oil (olive or almond) and black lead, will resist the action of the gas and liquor collecting in gas meters, as long as the dressing is not removed by chemical action. It was also shown by Dr. R. Lessing that leather, deprived of its dressing, will dissolve in the liquor; Mr. M. C. Lamb, of the Leather Sellers' Institute, denied this solubility in 1916, but Mr. Taplay amply confirms it. One of the chemicals which removes the oil dressing is ammonia, another is carbon disulphide, by itself, and more particularly in the various compounds which it forms by its reactions with ammonia and other constituents of the gas; the presence of benzol, &c., counteract this gradual corrosion. Sulphur dioxide, on the other hand, which is present in blue water gas, favours the corrosion. The oxidised tar oils in the gas and other constituents form resins which make the valves stick; when plenty of oil is present, or is purposely introduced, those resins redissolve and the meters operate normally again. Deposits of naphthalene also interfere with the action of the meters, and Mr. Parkinson's charts tend to show that the naphthalene curves and unaccounted-for gas curves run parallel. Some of the chemicals which attack the leather also attack iron and brass; solder and lead-coated tin plate are not corroded.

So far we have referred chiefly to the experience of the Gas Light and Coke Company. Mr. Parkinson's charts of the figures supplied by other companies lead on the whole to the same conclusions; but there are exceptions. Thus Tottenham used in 1915 more oil gas than before; yet the unaccounted-for gas percentage rose. The ammonia was also up in this year, however, and the increase in the oil may not have been sufficient to counteract the bad influence of the ammonia, which shows itself in most of the other figures, especially also in the case of the Gas Light and Coke Company, which in 1915 produced a gas rich in oil, but very low in ammonia. The cure for affected meters seems to be introduction of oil into the gas. This might be done by vaporising oil into the gas; a good deal of that oil would, however, be condensed in the mains before reaching the meters. Mr. Taplay suggested spraying the meters, either when they come back for repairs or when they are newly sent out. The former has been done with good results especially at the Kensal Green works and at Tottenham and Liverpool. Mr. Parkinson would periodically lubricate all the meters with the aid of a motor van carrying an oil-vaporising plant; the meter would be disconnected, be sprayed on the van and refixed, all without breaking the seal. The treatment cleans the slide valves, softens the leather and makes the meters record correctly again. The actual spraying takes only about a minute, as Mr. Parkinson demonstrated at the meeting. The method is due to Messrs. W. Fagan and W. Harris, of the Haggerston Meter Department; the apparatus used, which is called a pistol, works with an air pressure of 35 lb. to the square inch; the oil is the same as used for gas-making. At Leeds hot paraffin vapours are passed through the meters. Mr. Parkinson did not overlook that the public might object to his van-treatment of the meters—especially if the apparent result should be a higher gas bill.

Other weak points of the meters and of the Sales of Gas Act of 1859, which was drawn up long before the days of the pilot flame for incandescence burners, were referred to. That Act allows small (and large) meters to pass up to one-twentieth (one-fortieth) of their capacity unregistered; the annual gas consumption of all the by-passes, many of which take their gas unregistered, of the Gas Light and Coke Company is estimated at 500,000,000 cub. ft., which is equivalent to $1\frac{3}{4}$ per cent. of the make. There is further overdriving. According to the Act all meters are tested for accuracy at normal speed and at a pressure of $\frac{5}{10}$ in. of water, and this is done for station meters; but meters may be worked at higher pressures, and are as a fact habitually overdriven as to pressure. Driven beyond its normal capacity a new dry meter should register slightly fast, one would expect; but Mr. Fagan found in experiments that correct meters registered up to 3 per cent. slow when much overdriven. Apportioning the various errors, Mr. Partington suggests that the 5 per cent. of unaccounted-for gas may be made up as follows: $\frac{1}{2}$ per cent. bias of new meter in favour of consumer; 1 per cent. meter slow owing to overdriving; $1\frac{1}{2}$ per. cent. unregistered gas; $2\frac{1}{2}$ per cent. meter slow owing to its condition. Only the last two items could be eliminated or reduced by spraying the meters, Mr. Parkinson points out;

but one cannot help feeling that the whole estimates rest on uncertain assumptions.

We will turn to Mr. Taplay's analytical researches, of which, we should note, the printed paper submitted to the Institution gave only a brief account. In the dark brown liquors removed from various dry meters Mr. Taplay found, *e.g.*: (*a*) an oily part, consisting of unsaturated hydrocarbons and naphthalene (together 94·5 per cent.), pyridene bases and paraffins, further some iron; the iron had apparently been dissolved by carbon monoxide as ferrocarbonyl which would decompose in the presence of air; (*b*) an aqueous solution, alkaline, but not containing free ammonia, and consisting of sulphates, thiosulphates and thiocyanates of ammonia and iron, and of pyridenes; there was also a solid residue consisting of leather substance, which had evidently been dissolved; (*c*) a solid part, consisting to 91 per cent. of leather, and further of sulphates and oxides of iron, tin, zinc and some free sulphur (0·5 per cent.). The various liquors and their constituents were examined for months as to their action on tinned iron and dressed and undressed leather, also on brass, and the reactions between wet sulphur dioxide, carbon disulphide, ammonia, &c., were further studied. The oily portion (*a*) had no corrosive effects; the liquor (*b*) dissolved iron, with the liberation of ammonia, and leather. Of the various salts, ammonium sulphate and thiosulphate seem to be more corrosive to iron than the thiocyanate. Undressed leather was attacked by most of the substances; moist sulphur dioxide rots the leather as it attacks iron and brass. From dressed leather the salt solutions, as well as some of the salts, removed the oil dressing. The iron salts, once formed, seemed to be less injurious on the whole than the ammonium salts; but they are only the products of previous corrosion. Sulphur dioxide is produced in blue gas by the action of the air on the ferrous sulphide in the coke during the blow, and by the action of the steam on the carbon and ferrous sulphide during the run. The chief corrosion of the meters seems to be due to the interaction of carbon bisulphide and ammonia.

These conclusions were supported by the examination of dry meters. Some meters, the metal parts and leathers of which were found in excellent condition after five to thirteen years' service, were coated with an oil smelling like paraffin; half of this oil consisted of unsaturated hydrocarbons. It was on the strength of these experiments and observations that spraying with solar oil was started; that cured some meters which had stopped working and others which registered slow, the latter registering either correct or slightly fast. The cause of the stoppage or slow registration was that the valve stuck to its seat or was slightly raised from it, because resins, produced by the oxidation of tarry and oily condensates, had been deposited. The solar oil itself, it was ascertained, does not give rise to such resins, and the leathers of the Kensal Green district which have for years been subjected to a fog of paraffin vapours from the Botley plant in order to minimise naphthalene deposits, have remained in perfect order. The amount of paraffin oil sprayed into the gas is 0.0015 gallon per 100 cub. ft., whilst the amount of benzol, &c., stripped from the gas is 0.017 gallon per 100 cub. ft., roughly, 11 times larger therefore.

Many points in the chemistry of coal gas, especially the often disregarded influence of the minor constituents of the gas, no doubt require further elucidation. But the main problem at issue is the gas measurement. The imperfections of gas meters are acknowledged. The measurement of large volumes of gas, always impure in several respects, varying in composition, temperature and pressure, by the aid of instruments which must be very simple or at least not require attendance, is an exceedingly difficult problem, to which the chemical engineer will have to give renewed attention. Mr. Gibson mentioned during the discussion that they were experimenting at Liverpool with modified wet meters, and Mr. Lacey regretted the want of uniformity in the practice of determining the temperatures of station meters. There may be one thermometer, near the gas inlet or near the outlet, or two thermometers may be used, the mean of which need not correctly indicate the gas temperature. Temperature measurements of consumers' meters are not attempted. Sometimes these meters are boxed up in wood, to their advantage; they may be fixed in the basement or in draughty passages, exposed to all the temperature fluctuations of the seasons. Referring to dry meters, Mr. Parkinson said that in flats the only meter likely to be affected was the one on the ground floor—one does not quite see, why; valve troubles he considers more serious than diaphragm troubles, and automatic (slot) meters more reliable than ordinary meters. At Birmingham and Sheffield where wet meters predominate, little rise of unaccounted-for gas has been observed in recent years. Mr. Parkinson has certainly made out a strong *prima facie* case. As matters stand, however, with neither station meters nor consumers' meters really trustworthy, one can hardly say that the 5 per cent. unaccounted for is proved beyond doubt, or that it has been traced to defective registration by consumers' meters. New meters might upset the whole calculation. We are quite aware that 97 per cent. and even 99 per cent. of meters tested in London and other towns and countries have passed the tests in pre-war years; it is the service conditions which introduce the uncertainties.

## ACETYLENE FOR AUTOMOBILES.

The utilisation of acetylene is of particular importance for Switzerland, because acetylene is manufactured in the country largely with the aid of hydro-electric power. The experiments of Dr. H. Grossmann, of Zurich, on acetylene-driven motor cars were therefore supported by the Federal authorities. The preliminary account of these experiments in the *Schweizerische Bauzeitung* of October 5 last is very promising. There are difficulties, of course, but Grossmann is probably justified in expressing the opinion that the acetylene motor will be able to compete with the petrol motor even in normal times. The chief difficulties of using acetylene fuel in internal-combustion engines are that the compressed acetylene-air mixtures are themselves explosive, that the explosions are violent, and that the soot and possibly acids produced by the combustion may corrode the motor. The first two difficulties can be overcome, as we shall see, by diluting the acetylene with suitable gases or vapours; the soot deposition can be avoided by providing an ample supply of air. Air might indeed be regarded also as the simplest diluent to mitigate the violence of the explosion; Grossmann found, however, that the combustion of air-acetylene mixtures was always too sudden. Before passing to particulars we will refer to the methods of supplying acetylene on an automobile.

The acetylene can be generated on board, or it can be taken from steel cylinders containing compressed acetylene dissolved in acetone or in acetone substitutes. Such dissolved acetylene is relatively safer than gaseous acetylene (see Engineering, February, 1918, page 155), and its use offers manifest advantages. From the cylinder a 2-mm. steel or brass tube is taken to the reducing valve which is connected to the carburettor; no additional apparatus are required, and the car is always ready for starting and can go on until the cylinder is practically emptied. The disadvantages are that the cylinders are heavy and expensive, and not generally obtainable; the manufacture of dissolved acetylene is moreover itself difficult in abnormal times, since acetone has so far largely to be imported, like petrol. Journeys of thousands of kilometres were, however, made with dissolved acetylene, the large cylinders giving a range of 120 km. As regards the generation of acetylene from carbide on the car, there is plenty of carbide in Switzerland; it is almost everywhere obtainable at low cost, and there are hundreds of acetylene generators. None of those tested by Grossmann proved quite suitable; the acetylene has to be purified for one thing, whilst the cylinder gas is always pure; that problem may be left to the manufacturers, however.

The army authorities had insisted that the use of acetylene should not involve any change in the mechanism, and that the machinery should at once be ready for either fuel, acetylene or petrol. Since the acetylene had to be diluted, one complication is unavoidable, whether acetylene gas or dissolved acetylene is to be used; for this purpose an additional tank is provided, and further a set of nozzles by means of which the diluent can be proportioned. Quite a number of diluents appeared serviceable, common alcohol, benzine, petrol, light tar oils, naphthalene, water, &c., and at least 20 per cent. or 25 per cent. of these were required to make the combustion less explosive. In a Martini car of 12 h.p. to 16 h.p. the change-over to the acetylene mixture was effected by substituting a nozzle of 0·50 mm. for the 0·85 mm. nozzle. The percentage varies, of course, with the nature of the diluent; but an experienced driver was soon able to adjust his motor to the new conditions. Most of the diluents could be used as such; naphthalene and water required preheating of the carburettor. The use of water is the most interesting feature; Grossmann does not state what proportions of water he tried, but he made it answer both with the carbide gas and with dissolved acetylene. A mixture of acetylene with 20 per cent. of a mixture in equal parts of common spirit (alcohol) and light tar oil burned very well. Corrosion of the motor was not noticed after two journeys each of 1,000 km.; this motor was fed with dissolved acetylene. A motor boat was kept running for 6 hours or 8 hours every day for one month; the motor was found in good condition, although the acetylene was in this case generated in a common Tozzi apparatus and not especially purified. The motors did not run hot either, except in one case in crossing a pass, when half of the radiator was covered by an iron plate marking the car as an army automobile. The consumption of lubricant remained quite normal. As regards fuel consumption, we see that the motor which burned 14 kg. of benzine of density 0·75, on a trip of 100 km., did the same distance with a mixture of 4 kg. acetylene and 3 kg. of benzine. The fuel consumption was similar on longer journeys, and it would appear that 1 kg. of acetylene is equivalent to about 2·5 kg. of benzine. Since the calorific values of acetylene and benzine are 12,000 and 10,000 calories per kilogramme respectively, the equivalent ratio should be 1 : 1·2, and it looks as if acetylene were a more effective propelling fuel than benzine. Taking the prices now prevailing in Switzerland, motor propulsion by dissolved acetylene would be as expensive as with benzine, but propulsion by carbide and acetylene gas would only be half as expensive.

## THE INSTITUTION OF MECHANICAL ENGINEERS.

The first meeting of the above Institution for the Session 1918–19 was held on Friday last, the 18th inst., at the Institution of Civil Engineers, Great George-street, Westminster, the chair being occupied by the president, Mr. Michael Longridge. In opening the proceedings the president requested the secretary to read the names of fourteen members who had fallen in the service of their country since the last meeting of the Institution. Following the transaction of the ordinary business, Mr. Longridge announced that the council had, at their last meeting, nominated Lord Weir as an honorary life member, a distinction accepted by his lordship. It was further announced that 26 transferences had been made from the class of Associate Member to that of full Member.

### Hardness Testing.

Three papers bearing on the subject of hardness testing were set down for reading and discussion, one being entitled "A Law Governing the Resistance to Penetration of Metals when Tested by Impact with a 10-mm. Steel Ball; and a New Hardness Scale in Energy Units," by Professor C. A. Edwards, D.Sc., of the University of Manchester, and Mr. F. W. Willis, B.Sc. The second paper bore the title: "The Value of the Indentation Method in the Determination of Hardness," by R. G. C. Batson, of the National Physical Laboratory, while the third paper was contributed by Dr W. C. Unwin, LL.D., F.R.S., and was entitled "The Ludwik Hardness Test." All the abovementioned papers were read in abstract by their

authors. The paper by Professor Edwards and Mr. F. W. Willis was published in the May number of the Journal of the Institution of Mechanical Engineers, and as it covers to a great extent the same ground as the paper recently read by Professor Edwards before the Institute of Metals, and printed in full in our issue of September 13 last, page 285 *ante*, we have not considered it necessary to reproduce it. The two other papers read, namely, those by Mr. Batson and Dr. Unwin, we publish in full in our present issue on pages 475 and 478 respectively.

Professor Gerald Stoney, F.R.S., who opened the discussion, said that those who were interested in the subject were indebted to the authors of these papers, and also to Dr. Unwin, for the note he contributed to ENGINEERING of May 17 last (vol. cv, page 535), in which it was shown that the Martel and Brinell numbers had both the same physical significance—the pressure required to make the material flow—so long as the impressions were not too deep. It was easy to show that Professor Edwards' constant C had a simple numerical relation to Martel's D, and that $D = \frac{1,170}{C^4}$. Further, if the energy of impact required to produce, with a 10-mm. ball, an impression 2.5 mm. in diameter, as given in Table 35 in Professor Edwards' paper, were multiplied by 30, we also got the Martel number.

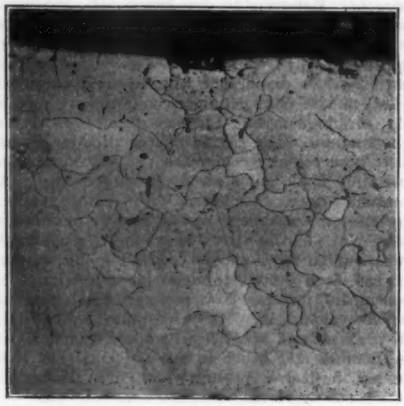

Fig. 1.

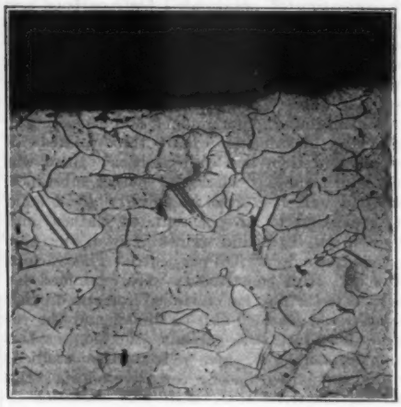

Fig. 2.

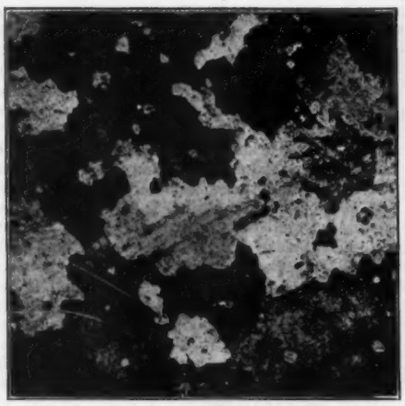

Fig. 3.

Fig. 4.

Fig. 5.

Professor Edwards' paper unfortunately measured the energy of the blow in pounds-inches and the diameter of the impression in millimetres, so that some care had to be taken in converting to the Martel number, which was in terms of kilogrammes per square millimetre. Plotting the Martel number D against the Brinell number H we got $D = 0.56\ H^{4/3}$; and Mr. Batson found that, allowing for the energy of the rebound, there was for most materials a constant relation between the Martel number $D^1$ thus found and the Brinell number, and that $D^1 = 1.5\ H$. It was thus evident that the energy of the rebound was a function of the hardness. The relation between the Martel number and the Brinell number was also given in Fig. 8 of Professor Edwards' paper; but the horizontal scale was not marked; it was apparently 20 lb.-in. per division, or 600 Martel numbers.

An important point brought out in the papers was that for various amounts of striking energy and for various forms and sizes of indenting tool the Martel number over a wide range was constant. For ductile materials there seemed to be some relation between the Brinell hardness and the tensile strength; for steel Dr. Stead gave tensile strength = 0.22 Brinell number; and a somewhat similar rule was given in a recent number of ENGINEERING. It would be interesting to know whether such a relationship held with materials such as copper, lead, tin, &c. Although not strictly connected with the matters under discussion, the fact might be referred to that in the paper read by Professor Edwards before the Institute of Metals it was shown that hardness was a function of the periodic law of atomic weights. It was known also that the melting-point was a function of the periodic law, and he thought that a step had been taken here towards getting at the real constitution of matter.

Mr. D. Hanson, who spoke next, remarked, in relation to the results obtained by the Brinell and Martel tests, that it would appear at first sight that the property of the material measured was the same—resistance to indentation; that this was so had been assumed by the authors of the papers and by the previous speaker. The outward results in the Edwards' and Batson tests were the same; each gave a spherical indentation of the metal. Account, however, was to be taken not of the shape of the indent but of the process taking place in the metal when the indent was formed. Mr. Batson had kindly enabled him to examine a number of samples of different metals indented by the Martel and Brinell methods, and in this connection the speaker exhibited a series of slides, remarking as follows in relation to each:—The first slide (reproduced in Fig. 1 annexed) was a section taken through the Brinell impression in a piece of Armco pure iron. The top surface of the section represented the bottom of the impression, and Mr. Hanson wished to draw attention to the practically undistorted crystalline structure of the material. The material was no doubt deformed during the test, but the amount of deformation of the crystals themselves was so small as to be unobservable in such a section. The second slide illustrated a section from the same specimen, taken at the edge of the impression. Both the sections were from a Brinell impression. The third slide (reproduced in Fig. 2) showed a section of the same material taken through the bottom of an impression made by an impact machine. He would direct particular attention to the narrow parallel bands, with the appearance of twin crystals. These were the Neumann lamellæ produced in iron and some other metals under shock; these lamellæ were not found in the sample tested by the Brinell method, but were found in abundance in samples of iron tested by the Martel method. The fourth slide represented the same case, but taken at the edge of the impression, showing the Neumann lamellæ, not found near the surface but further into the material, while the fifth slide showed a section taken rather further from the surface, the Neumann lamellæ appearing in comparative profusion. Slide No. 6, reproduced in Fig. 3 annexed, illustrated observations on a specimen of wrought and annealed tin, the surface being polished carefully and etched. The photograph showed the structure of the etched material. One section was tested by the Brinell and another by the Martel method. The seventh slide, reproduced in Fig. 4, showed the surface of the material after testing by the Brinell method; the direction of the slip bands produced during deformation was apparent. The metal had been deformed according to the ordinary rules which it was customary to apply to the deformation of metals. The slipbands were not very clear, since recrystallisation of the deformed material took place, with the formation of a number of minute crystals. The last slide shown (which we reproduce in Fig. 5) represented the surface of the same metal in the neighbourhood of the impression, after testing by the Martel method. The mechanism of deformation was entirely different. The surface crystals were covered with a series of metal twin crystals, and the whole method of deformation was quite different from that found in the specimen tested by the static method.

Mr. Hanson further remarked that he had made similar experiments with aluminium which, however, showed no sign of difference between the method of deformation under the static and under the dynamic tests. He mentioned these results

because he felt that in drawing deductions as to the definite relation between the Martel and Brinell numbers, it was desirable to take into account the actual property of the material to be measured. In the cases of tin and iron, particularly the latter, it was essential to bear in mind that one property was being measured by the adoption of the Martel method and another property by the use of the Brinell method. Very pure iron was abnormal and did not obey the fairly general rule that there was a definite relation between the Brinell and Martel numbers. Mild steel, however, which was not very different in constitution from pure iron, appeared to be normal, as also did boiler plate, another mild steel; indeed, most of the other steels tested appeared to be normal. There must, however, be some point between the pure iron and the steels at which the metal was deformed, partly by one method and partly by another. In the iron itself deformation appeared to take place normally along the surface, but abnormally further into the material. He would ask the members to take these observations into account in discussing the results of the tests. He should mention that a suggestion respecting some of the abnormalities which occurred had been made in a previous paper by Professor Edwards. The work that he (the speaker) had done in connection with Mr. Batson's results had proved the correctness of that suggestion for some of the materials. Messrs. Edwards and Batson had observed, in relation to the conditions in which the values for the constants C could be expected to apply, that: "If these conditions are fulfilled, the deformation will be confined to the zone immediately under, or concentrated within a very limited area around, the ball." The speaker would ask the precise meaning of "very limited area." He had, in tests he had made, been able to observe visible deformations—indicating fairly considerable deformation—at a distance very considerably below the actual impression; below an impression of $\frac{1}{4}$ mm. he had detected deformation at a distance of 7 mm. from the surface of the metal; or 14 times the depth of the impression itself. The authors' statement required therefore further consideration. In answer to a question by Mr. Pendred, Mr. Hanson said that the observation just mentioned was made in the case of a dynamic test.

Dr. W. C. Unwin, before criticising the paper by Dr. Edwards and Mr. Willis, commented on the care with which the investigation had been made, indicated, among other things, by the fact that the results plotted into a smooth curve. That, however, did not prove that the ordinates of the curve were a measure of hardness, but they were a measure of hardness plus other things. Dr. Edwards deduced his hardness figure from the total energy of the falling monkey, consisting of two parts, one causing indentation and the other showing the energy of rebound. The speaker urged that if the hardness of a metal depended on the energy causing indentation, that hardness should be deduced only from the energy that had caused indentation, and not from the sum of two parts, one of which had nothing to do with causing indentation. Energy of rebound was no doubt partly due to the elasticity of the material itself, but was also due to other things, such as the elasticity of the supports of the test piece. In part also it was due, especially with the ram or monkey used by Dr. Edwards, to the elasticity of the monkey; questions which had nothing to do with the hardness of the metal. He was surprised that Dr. Edwards should not have known that many other people had been using the dynamic test of hardness, since it was the oldest test of hardness, although the way of expressing results was bad. Such a test of hardness had been used by Dr. G. Calvert when the speaker was an apprentice. An inspection of Martel's papers had shown the speaker that Martel was aware of the importance of the rebound. In giving practical directions for making his test Martel had said: "All latitude may be left to the experimenters in choice of weight of monkey and height of fall, but the height of fall should be so regulated as to avoid rebound of the monkey." The speaker did not suppose the rebound could be altogether avoided, but weight and height of fall could be so arranged that the rebound would be very small and its effect negligible. He was inclined to think that the rebound was smaller with the kind of indenting tools, pyramidal and conical, used by Martel than it was with the spherical tool. In Table No. 35 of Messrs. Edwards and Willis paper, the figures were in different and not easily comparable units. They could, however, be more readily compared as follows, taking the hardness of mild steel as a standard:—

*Relative Hardness (Dr. Edwards' Table, 35).*

| Sample. | Edwards and Willis. | Brinell. | Shore Scleroscope. |
|---|---|---|---|
| Mild Steel .. .. .. | 100 | 100 | 100 |
| Tin .. .. .. .. | 6 | 14 | 33 |
| Copper .. .. .. | 78 | 110 | 132 |
| Medium Steel .. .. | 199 | 197 | 139 |
| High Carbon Steel .. | 317 | 261 | 228 |

These methods could not all be methods which afforded any rational measure of the hardness of the materials; the hardness figures were "all over the shop."

Turning to Mr. Batson's valuable paper, Dr. Unwin had found therein no reference to time effect, an important point in hardness testing. As the speaker had said, the loads in the Brinell tests should be so arranged that the indentations were geometrically similar. His own impression was that properly reduced, the Martel and Brinell numbers coincided, but if they differed he would, of course, give way on the point. As to the best test of hardness, he was inclined to favour the static load as the most convenient in most cases, but in other cases the impact method was more convenient. He preferred some form of truncated cone or pyramid for the indenting tool. In cone measuring, it was possible to measure the depth of the indentation while the test was going on, without the trouble of afterwards using the microscope to measure the diameter. Mr. Batson had mentioned an instrument for measuring the depth of indentation during the test, and the speaker imagined this to be the same instrument as that supplied with the Ludwik tester, in which mercury was forced into a capillary tube. There was a mechanical method of measuring the depth during the test introduced by Amsler, which the speaker regarded as more convenient. In conclusion, he thought it would be necessary in order to arrange a test which would give the true relative hardness with different materials, to adopt some standard graduation of the load, depending generally on the hardness. Knowing, say, within 10 per cent. of error, the hardness of the material, it should not be difficult to state the load required to give an indentation of specified volume.

Sir Henry Fowler, K.B.E., referred to the fact that the original work by Messrs. Edwards and Willis was done with a view to ascertain hardness at varying temperatures. He believed that considerable information might be available if the hardness of certain light alloys at varying temperatures were determined. It was only after much investigation that Dr. Edwards concluded that it would be absolutely necessary to have an impact test. All would agree with Dr. Unwin that the impact test was historically the first. He felt that although the ordinary static test was useful for research work, there was nevertheless a great field for an impact tester of the type such as that with which Mr. Batson had worked, but of a larger size. The smaller type had the disadvantage that the indentation produced was so very small. A point which had caused the speaker some concern was connected with the shape of the indentation—not of the hole, but of the crater formed round the hole. After seeing the interesting slides exhibited by Mr. Hanson, he felt that additional information as to the flow of metal under pressure—in that case static—would be found if a microscopical investigation could be made of the crater which, in certain metals, was formed round the edge of the hole. This might be done by examining microscopically impact test results at various temperatures. He hoped therefore that the work done by the authors would not be closed by the results recorded in their papers, but that further investigation would follow.

Mr. H. L. Heathcote wished to ask Mr. Batson whether the depressions were actually measured for volume. Volume of depression was spoken of in the paper, presumably calculated from the diameter of the depression. If that were the only method used in determining the volume, it introduced a great chance of error. The actual depth measured did not correspond to what would be expected from an application of the relation between the radius of the ball and the diameter of depression formula. Some years ago the speaker had experimented with the auto-punch referred to by Mr. Batson. With a $\frac{1}{16}$-in. ball and a small punch, he found the radius of the depression always larger than he had expected. The radius of the $\frac{1}{16}$-in. ball was 0·09375 and that of the depression 0·1145 in the case of one specimen and in the case of other specimens the figures were 0·0975, 0·0981 and 0·0951. In the case of a $\frac{1}{4}$-in. ball, with a radius of curvature of 0·125, the results obtained were 0·1701, 0·1532 and 0·1296. Such results affected profoundly the volume of the depression. His own method of measuring the volume of very small depressions was to use a microscope of fine adjustment focussed first on the edge of the depression and then on the bottom. To calibrate the fine adjustment, he took a piece of steel with a step on it, the step being measured with a Newall measuring instrument. The same piece was put under the microscope and by focussing down he scaled his microscope in terms of actual length. Mr. Heathcote then explained diagrammatically an instrument which he believed had not been shown before, and which had been found useful for measuring small, thin specimens such as cartridge cases, &c. Essentially, this instrument consisted of a pair of legs with an anvil, which took the case or specimen. At the top was a piston moving in a cylinder. At the end of the piston, which just came through the face, was a small ball, and at the back of the piston was a spring. The locking arrangement shown could be used to adjust the compression on the spring. When the specimen was placed on the anvil the ball moved away and the spring was compressed, any excess pressure being taken by the face through which the ball projected, the actual pressure between the ball and the specimen being, therefore, quite independent of the pressure exerted by the hand. The diameter could then be measured, and the means were afforded, by the small instrument described, of measuring very thin specimens, and maintaining, in the instance of cartridge-case walls, the hardness at exactly what it should be.

Sir Robert Hadfield, who spoke next, regarded the papers as a result of the excellent work done by the Hardness Research Committee, presided over by Dr. Unwin, to whom a deep debt of gratitude was due for the way he had taken up this important subject, as well as for the manner in which he had lately been travelling about the country and lecturing as he had done. Speaking as a member of that committee just named, he might say that it afforded him the greatest pleasure to work with Dr. Unwin, who invariably kept to the point and allowed no wandering. The speaker felt that the report presented a couple of years ago had done great service; he had found it of great use for reference, and believed that others had done so. Turning to the papers, in Table 3 of Mr. Batson's communication, certain hardness figures were given by static test, namely, for mild steel 120, which the speaker believed would, by the dynamic test come out at 190, while the figure of 128 for boiler plate would be represented by 210 under the dynamic test. Taking the harder steel, the high carbon steel, the figures 236 in the table would be 340 to 360. These figures were interesting, but he wished the author would add the results for hardened steel specimens. Dr. Edwards had referred in his paper to hardened steel, but he had not noticed any reference by Mr. Batson; he alluded to Brinell hardness of 600 and upwards. Perhaps Mr. Batson could add that information before the paper was finally printed. He supposed that the results would show the very high hardness number of 1,000 to 1,100. Those who had to deal with steel in the hardened form would realise what high figures those were, and particularly would they be realised by those who were dealing with a ball of a very superior nature, arriving at a high velocity, namely, the armour-piercing

shell. If the dynamic test showed the very high figure he had suggested, the enormous forces brought to bear on the point of a hardened steel projectile would be understood. In our modern large calibre guns we had heat engines developing, in parts of a second, an energy of 150,000 ft.-tons, which was, of course, imparted to the projectile. The projectile had to get rid of that energy on meeting the plate, and it was evident that the stresses on the hardened steel would be enormous. It was for this reason that he hoped Mr. Batson could throw more light in that direction. The severity of the problem in the case of a modern armour-piercing shell would be grasped when he pointed out that the hardness of the Brinell ball number for K.C. steel was 600 to 650. Sir Robert hoped that the papers under discussion would not introduce confusion. The Brinell standard number provided a kind of "light-house" to those dealing with steel, and that number should not be departed from. He personally would deprecate any confusion which might arise, as he believed it would have been impracticable for him to have conducted a large number of his experiments without the guidance of the Brinell number.

On the question of the smallness of the indentation, Sir Robert considered that, by the use of proper measuring instruments, it was easy to measure, when necessary, the width and depth of the indentations produced. In conclusion, he would like to refer to the great credit due to Professor Turner, of Birmingham, for the work he had done in the early days, before the time of Brinell. Professor Turner had been the first to call attention to hardness testing by the scratch method, and the gratitude of metallurgists was due to him.

Mr. T. Main desired to refer to the time-effect in the Brinell test, and especially to Guillery's test in that direction. At the Hadfield Research Laboratory the experiment had been made of keeping the load on for two or even five minutes, and comparing the impression with that given after, say, 10 seconds. The experiment did not quite confirm Guillery's results; there was little practical difference as between 10 seconds and 2 minutes, not, at all events, so much as Guillery indicated. The test was easy to make, and others might wish to carry it out and compare results with the speaker's and Guillery's experience. In considering work of the kind covered by these papers, two stages had to be taken into account, first, the experimental work and establishment of the empirical formulæ and, second—this being often overlooked—the establishment of a scale of hardness from the empirical formulæ. It did not necessarily follow that the constant in the empirical formulæ was a measure of the hardness. In so speaking he was only following up the remarks of Dr. Unwin. Dealing with the experimental work and the table of empirical formulæ, he had wondered at first how it was possible, in similar work, to obtain two such different formulæ as Dr. Edwards and Mr. Batson had derived. Mr. Edwards' formula involved the fourth power of the diameter of the impression, while Mr. Batson's involved the cubic dimensions of the impression. But analysis of the two formulæ showed them to be essentially the same. Making the usual assumptions covering small impressions both would reduce to the same form as the Brinell formula. Mr. Batson's formula, being in the same units, reduced to the Brinell formula, and strict comparison of the figures was possible. Sir Robert Hadfield had pointed out that the figures for the dynamic test were higher than those for the Brinell; they could not therefore be a substitute for the Brinell test. The speaker suggested the inertia effect as the cause of the increased hardness number. With regard to work hardening, in the Brinell test, as the diameter of impression increased, the hardness number went up; not so with the Batson dynamic test. The speaker would ask, therefore, what had become of the work-hardening effect? It appeared impossible to say. The objection had been raised to the Brinell test that it gave different hardness figures for different depths of impression, but, in the view of the speaker, it would be wrong if it did otherwise. Assuming the definition of hardness to be resistance to penetration, there was no doubt that the stress on the ball or material was greater as the penetration deepened, just as in the case of tensile or compression tests the stress increased with the increase of elongation or the value of the compression. In the Brinell test the amount of deformation should be specified, and, as Dr. Unwin had suggested, the same geometrical shape of impression should be aimed at. If Brinell had erred anywhere, it was in not specifying the load; he had probably been led into that mistake by over consideration of practical difficulties. Turning to the establishment of the scale of hardness from empirical formulæ, Mr. Main said, the criteria of hardness were so many that it was comforting to be able to discriminate between them. Therefore he thought too much stress could not be laid on the fact that the scale must be rational. A rational scale had these advantages; it allowed the statement that one material was twice or three times as hard as another, and it also allowed comparison of different kinds of hardness—scratch hardness, wear hardness, &c.—as it was possible to state just how the material behaved under the different kinds of test. The first criterion of a rational scale was this, that the physical dimensions should be right; the second, that the hardness figure should not involve any terms which brought in any characteristics of the testing apparatus, such as the diameter of the ball, &c. With regard to dimensions, whatever the form of hardness considered—in the case under discussion it was resistance to penetration—the unit must have the dimensions of the stress, like any other property expressing the strength of a material. If that point were properly borne in mind, he felt that more progress would be made. Mr. Batson's formula, judged by that criterion, would reduce to the Brinell formula, and possessed the dimensions of the stress and the pressure over an area. Dr. Edwards' formula, on the other hand, involved the diameter of the hole and also an arbitrary diameter of the impression. Still worse was Dr. Edwards' other coefficient of hardness, C. In the first place it was a measure of softness and not of hardness, and its dimensions were, he feared, far from being "a stress." He had recently raised the same point in connection with shock tests; he believed the wrong unit was being used for the shock strength of a material, and this delayed progress. This strength was usually expressed in kilogrammetres divided by area; if, however, the unit was to be rational the unit should be kilogrammetres divided by cubical dimension or volume.

At this point the president then brought the proceedings to a close, announcing that the discussion would be resumed at the next meeting of the Institution which will be held on the 15th of November.

## THE CERAMIC SOCIETY: REFRACTORY MATERIALS SECTION.

The fifth ordinary meeting of the Refractory Materials Section of the Ceramic Society was held at the Technical College, Swansea, on October 17 and 18, 1918. Mr. W. J. Jones, Deputy Controller of Iron and Steel Production (Ministry of Munitions, London), presided over a large gathering of members, and there was again a very full programme.

Mr. J. Allen Howe, B.Sc., in his "Notes on the Refractory Materials of South Wales," stated that the silica rocks, fireclays and dolomitic limestones which constitute the refractory raw materials of South Wales are practically all obtained from the carboniferous strata. The first silica bricks ever made were made in the Vale of Neath nearly 100 years ago, and these Dinas bricks soon acquired a high reputation, which they still maintain. The silica rocks—quartzites, sandstones, grits and conglomerates—suitable for making silica bricks are mainly confined to the basal grit or the lowest of the three divisions of the millstone grit, and there is an abundant supply of material, though the beds of rock are not constant in character. The type most preferred is a hard, compact, fine-grained quartzite tinted buff (or cream), purple or blue. These rocks consist essentially of angular and subangular grains united by a siliceous cement. In most of them the grains average 0·1 mm. to 0·2 mm. diameter, but in some they are 0·3 mm. to 0·5 mm., and in others they are somewhat larger than the first-named, with occasional small pebbles of quartz and chert. Typical samples contain 98 per cent. silica or rather less.

Fireclays are obtained only from the Middle and Lower Coal Measures, though some are known in the Upper Series. Some details were given. Of the great bulk of the clays of South Wales very little is known.

Dolomite limestone occurs pretty abundantly in the Carboniferous Limestone Series of South Wales, but quantity and quality are only satisfactory in certain localities, as about Clydach (near Abergavenny), near Cardiff and Pontypool, at Machen and Risca, also near Mumbles Head, &c. The beds are very liable to change rather quickly in composition, and especially in silica content.

In "Magnesite as Raw Material," Mr. T. Crook gave a historical review of the application of this material, followed by a discussion on the economic classification of magnesites, with descriptions of the more important occurrences, and including various analyses, statistics, &c. The siliceous magnesite of Baudissero (Piedmont) seems to have been used about 1800 and earlier for making porcelain, on the supposition that it was a high-class china clay. Giobert, after analysing it mixed it with clay and made refractory crucibles. Magnesia crucibles were used in France for fusing platinum. In 1866, Caron pointed out the importance of magnesite as a source of refractory magnesia, and in 1868 described the method of making magnesia bricks, from Euboean (Grecian) magnesite, laying stress on their suitability for use in the Siemens-Martin furnace. The process used by Caron was to "dead-burn" the bulk of the magnesite, and after being broken up and the impurities removed, the sandy residue was mixed with caustic magnesia as a binder. After adding 10 per cent. to 15 per cent. of water, and moulding under pressure, the bricks hardened on drying, and after burning, became very refractory. Sorel afterwards added magnesium chloride to form oxy-chloride cement. It was not until about 1880 that Spaeter and Co. went to the Veitsch district of Styria. Previously, and to some extent even afterwards, the Germans seem, like the French, to have used compact magnesite for making magnesite bricks.

For the economic classification of magnesites, texture and composition may be made the basis, giving the types:

(1) Spathic breunnerite (*e.g.*, Styrian).
(2) Spathic magnesite (*e.g.*, Quebec, Washington, Norwegian).
(3) Compact magnesite (*e.g.*, Grecian, Californian, Italian, Indian and Australian).
(4) Hydromagnesite (*e.g.*, Atlin, in British Columbia).

The first two of these show cleavage. Compact or cryptocrystalline magnesite shows no cleavage, but is generally firm in texture. Hydromagnesite is powdery or very friable. (1) has much ferrous carbonate mixed with the magnesium carbonate, whilst (2) is almost free from ferrous carbonate. Both (1) and (2) are generally associated with dolomite, but the admixture of dolomite is less intimate in (1). Compact or cryptocrystalline magnesite is often mixed with quartz or serpentine, but is usually fairly free from lime. The hydromagnesite of Atlin is remarkably low in impurities.

The fragments obtained by coarse crushing are likely to be purer in a coarse spathic magnesite or breunnerite. When calcined, breunnerite also blackens owing to formation of magnetic oxide, and besides being more easily cleaned from impurities by hand-picking, can be dressed magnetically to exclude dolomite, and so the quality of the sinter can be controlled. Breunnerite loses the carbon dioxide from ferrous carbonate at a rather lower temperature than from magnesium carbonate. The formation of magnetic oxide by calcination probably increases the thermal conductivity of the mass, in which case the sinter derived from breunnerite should reach the temperature of the kiln more rapidly and uniformly than the purer magnesia from non-ferriferous magnesite. The fairly definite chemical and physical changes in the sintering of breunnerite serve to explain the kiln economy that is claimed for the sintering of breunnerite as compared with compact magnesite. These changes may be summarised as due to (1) the cleavages giving the kiln gases access to all parts of the mass; (2) the formation of magnetic oxide, involving oxidation and increased thermal conductivity; (3) segregation of iron oxide by combination with magnesia to form magnesioferrite (which occurs as microscopic granules scattered through a matrix of periclase).

Grecian and Indian (Salem) magnesite would be much more economically imported as sinter.

Besides a number of analyses, the paper also contains production statistics, &c.

Mr. G. W. Mottram's paper on refractory bricks made from non-plastic materials raises interesting and important points. Incidentally, he recommends rotary kilns for calcination of magnesite, &c. The practice of using Portland cement very finely ground, and mixing these fine particles with coarser materials is commended as a means of increasing strength. In applying the same idea to firebricks, it is stated that satisfactory results were obtained with 90 per cent. grog and 10 per cent. fireclay, when the raw clay was ground to a fine slip with two or three times its

weight of grog, and the resulting mixture afterwards mixed with the rest of the ground grog. Bricks so made from calcined Stourbridge fireclay showed no contraction after repeated burnings, and after a week's exposure in the port of an open-hearth steel furnace came out with the edges quite sharp, as in sample exhibited. This method is specially applicable to preparation of material for silica bricks. By grinding 15 per cent. to 30 per cent. of the material with lime, clay, or other binder to a fine slip, and then adding this mixture to the remainder of the graded silica material, the necessary fine material is assured to fill in the voids, and to act almost as a cementing medium, and also the binder is brought into intimate contact with every particle of the silica. With two such dissimilar materials as silica and lime, it is not possible to get a regular and uniform mixture with a breaker and 15 minutes to 20 minutes grinding in a solid-bottom pan.

Le Chatelier recently published the results of tests of bricks made by a similar process in a French works and burned at 1,400 deg. C. With all fine material the crushing strength reached 4,540 lb. per square inch. With coarser grains (passing 100-mesh, and retained on 120-mesh), 993 lb. per square inch, with fine and graded grains up to $\frac{1}{4}$ in. the average was 3,095 lb. per square inch. The durability of such bricks was found to be increased 200 per cent. to 300 per cent.

When all fine grinding is used, the permanent expansion can be eliminated, but in the preferred graded mixture it amounted to 1·6 per cent.

Mr. Mottram believes that by this method of preparation many silica rocks may be used with satisfactory results, which have hitherto been useless for bricks.

In a study of silica products, forming a continuation of a paper read at Sheffield, Dr. A. Bigot treated only of silica products used in the Siemens-Martin or similar furnaces. This paper arrived too late to be included in the printed programme. The manufacture of such products is briefly described, and the results of tests for density, porosity, and crushing strength at ordinary temperatures and after heating at 1,710 deg. C. It has been ascertained from microscopic investigations that tridymite is formed rather rapidly in the presence of lime at high temperatures, this formation being much slower where the rock grains are not in contact with lime.

As regards burning the products, it is stated that in the author's tunnel kiln at 1,500 deg. to 1,550 deg. C. the duration of a good burning from set to draw is from four to five days, and the tunnel kiln expends scarcely a third of the fuel consumed in the burning of intermittent kilns. A description of such economical kilns is promised for a future article.

In an appendix the results of an investigation of silica bricks which had been for some time in the arches of Siemens-Martin furnaces are described. Such bricks show three very distinct zones, a zone of unaltered silica brick, an intermediate brown zone with scattered white silica grains, and a grey zone without visible white silica grains but having its surface in direct contact with the furnace atmosphere covered with a coat of brown glaze. The brown part occupies three or four times the space of the grey part. The composition is variable, but the brown part contains relatively more iron than the grey part. The iron in the grey part is in the ferrous state and is not attracted by the magnet, whereas in the brown part it is partly in the ferric state and about half is attracted by the magnet. The furnace gases reduce iron oxide in the grey material through local reducing conditions resulting from osmosis. Under the action of the external air, the iron in the brown part passes into the ferric state. For the formation of the grey part, which is apparently indispensable, a semi-oxidising and semi-reducing working condition of the furnace seems preferable.

The stability of the bricks and silica products depends not only on their manufacture, but also on the behaviour of the furnace in which they are used, which varies with the works and the management.

Two new materials are formed in the arches of Siemens-Martin furnaces, a brown product and a grey product, the latter in particular showing increased crushing strength.

The author concludes that (1) contrary to prevalent opinion, the grey parts of the bricks, containing only 85 per cent. of silica, are as refractory as products with 95 per cent. of silica, and are far better at all temperatures as regards crushing strength; and (2) that more than 3 per cent. or 4 per cent. of lime and iron oxide together is not necessarily detrimental in silica products, for the grey parts of bricks contains 10 per cent. to 14 per cent. of them. A second appendix describes the Bodin method of measuring crushing strengths.

Dr. J. W. Mellor and Mr. W. Emery, in a paper on "The Corrosive Action of Flue Dust on Firebricks," described the results of a number of important experiments carried out in a special furnace, an account of which is given. Special attention is required for the distance the brick is placed away from the burner, the rate of heating and maximum temperature reached, the time the brick is exposed to the maximum temperature before dust is allowed to enter, the amount of dust and rate at which it is fed on to the brick, and the time the brick is kept heated after the dust has all been used. The treatment of the brick is such as to give in a few hours results which might require months to produce in industrial furnaces.

The dusts used included boiler dusts, dust from the top of the retort bench of a gas works, dust from the slag chamber between steel smelting furnace and regenerator, dust from blast-furnace Cowper stoves, and various powdered substances, including bull-dog, tap cinder, red hematite, lime from calcined marble, salt, lime and common salt, sodium sulphate, salt and potash spar, sodium silicate with calcium silicate.

Analyses of dusts are given. In preliminary experiments it was found that below 1,300 deg. C. the action of the dust is mechanical rather than chemical, so a temperature of 1,400 deg. C. was maintained.

Analyses of firebricks are also given, including two typical fireclay bricks, one of moderately close texture with very hard and compact grog fragments of medium size, and the other with rather coarser grog and much more open texture. There were also three silica bricks, one with fairly coarse grains and somewhat open texture (not uniform), another very fine-grained of uniform but not very close texture, and the third close-grained and dense with medium grains.

The general results are as follow. In general the penetration by the dust is greater in fireclay bricks than in silica firebricks. In most cases the bond is attacked first, and coarser grains last. In silica bricks the depth of penetration by the dust is generally less the finer the grain. In the fine-grained bricks the coarser grains and the bond are both attacked, while in the coarse-grained bricks the bond is alone attacked to any serious extent. It follows that the bond of a silica firebrick offers the feeblest resistance against a corrosive slag. The attack on the coarser grains of a silica firebrick varies with the nature of the latter grains, the penetration of the rock fragments by the dust being greater than in the case of a compact rock made up of interlocking grains. Under oxidising conditions iron oxide does not corrode silica bricks to any noteworthy extent, but under reducing conditions ferrous silicate forms and acts as a corrosive flux. In the trials with bull-dog the silica brick was far less attacked than a fireclay brick, and generally the iron oxides corrode the fireclay bricks more than the silica bricks.

The dusts apparently favour the conversion of the quartz into the low specific gravity form or forms even where the coarse grains have apparently not been penetrated. This is probably in part due to the vapours of the alkalies in the dust. Where the dust can form a surface glaze the subsequent rate of attack is considerably diminished. This corresponds with a well-known practice of smearing with a glaze mixture the face of the brickwork in certain kilns. If the surface glaze be fluid enough and in such a position that it can flow to a lower level these remarks do not apply, for the brick is rapidly eaten away as soon as the glaze begins to drip.

It has not been found possible to express the results of the corrosive action of flue dusts in a quantitative manner by weight, by measurement, or by graphic diagram. Photographs are not satisfactory, and depth of penetration is not sufficiently reliable for a quantitative test. It is possible that the testing of the effect of a given dust on a refractory may be best carried out by moulding mixtures of the dust and the ground refractory in definite proportions, in the form of cones, and determining the fusing point.

Dr. J. W. Mellor presented the committee's report on "The Standardisation of Tests for Refractory Materials (Part II)." It relates to the grading of clays, &c., according to the size, of grain, and to the corrosive action of flue dusts on refractories.

The object of mechanical analysis is to sort the particles of the clays into groups, so that each group shall consist of particles between certain specified limits of size. In some cases the ordinary sieve analysis will suffice, but in the finer-grained clays the great bulk passes through the finer lawns.

In the case of sieve analysis, for testing purposes it is well to use lawns with a standard gauge, as the sizes of apertures in commercial lawns are indefinite and vague. The standard lawns of the Institute of Mining and Metallurgy are suitable. The sieve process works best if the material be slopped and the fine stuff washed through each lawn. The residue on each lawn is then dried and weighed. With the more coarsely ground materials, as commonly used for silica bricks, a set of three lawns, say No. 5, No. 50, and No. 120, will suffice. Ordinary lawns of an equivalent size will probably suffice for works practice, and three other sizes may sometimes be more convenient. For clays and the finer ground materials (flint, &c.) the elutriation process is perhaps the most convenient method. A full description of the preliminary and subsequent treatment is given.

For the corrosive action of flue dusts on refractories, the furnace and method of the preceding paper (by Mellor and Emery) may be used, and though there is no satisfactory method for measuring this action, the effect can be observed, qualitatively. The points requiring attention are enumerated in the preceding paper.

Mr. H. C. Meyer, of Philadelphia, in a paper on "Zirconia: Its Occurrence and Application," gives many interesting details concerning that remarkable substance and its associations, which from considerations of space can only be lightly touched upon. A number of analyses give some indications of the range of composition. Its application as a refractory has been the subject of discussion for some time past, and it may be recalled that it possesses a most unusual combination of properties in high refractories, high resistance to corrosive action of slags and vapours, low coefficient of expansion and low conductivity for heat. The results are given of various tests made with the raw or partly purified material, alone and mixed with magnesia or kaolin or certain siliceous fireclays as binding material. Bricks of "zirkite" (a trade name for the commercial ore of mixed minerals as found native) are stated to be much used in America for lining electric furnaces. The American method of manufacturing "zirkite" bricks consists essentially in crushing the ore, and grinding to about 60-mesh in a dry pan, passing over inclined screens to remove all particles finer than 100-mesh, and bonding the product so obtained with "zirkite cement" (or water-ground "zirkite"). The refractory mass is made of about 50 per cent. of 60-mesh "zirkite" and 50 per cent. of "zirkite cement." The mixture is made into a stiff mud with water and moulded in the same fashion as silica bricks. The bricks must be dried very slowly to avoid air cracks, and owing to their brittleness great care is needed in setting them. The loss is rather high, but warped articles and cracked bats can be ground to be used again. Besides various uses of zirconia as a refractory, other compounds of zirconium are used for various purposes, and ferrozirconium is finding application in the steel industry as a hardening agent, as a scavenger for removing nitrogen and oxides from steel, in making drawn filaments for incandescent lamps, and zirconium alloyed with nickel is used for the production of high-speed cutting tools. It may be added that zirconia makes the best substitute for tin oxide in acid-proof enamels.

The last paper, on "Refractories in the Zinc Industry," by Mr. J. A. Audley, B.Sc., was mainly concerned with the materials used in making the zinc distillation retorts, and the changes, both chemical and physical, which take place during use in the zinc furnace. An interesting feature among these changes is the transformation of much of the quartz and combined silica in the retort material into tridymite, as is known to occur in silica bricks when heated to high temperatures. With reference to the possibility of improving retorts, it is suggested that the formation of surface cracks may perhaps be limited or prevented by the use of suitable protective coatings, such as fused bauxite or zirconia. Addition of some carborundum or like material to the retort mass is mentioned as a means of increasing thermal conductivity. The casting process is alluded to as a ready means of applying special coats.

The chairman (Mr. W. J. Jones), in the course of a speech, observed with regard to the Welsh silica brick industry that the total monthly output, expressed in terms of 2½-in. silica squares, increased from 2,155,000 in July, 1916, to 3,780,000 in November, 1917. The question of precalcination of silica rock was mentioned as needing further investigation, and the opinion was expressed that if a continuous process were employed the additional cost of thus eliminating the effects of expansion would not be heavy. The enormous development of the basic process for the production of steel was indicated by the increase of British ingot capacity from 7,500,000 tons per annum before the war to 12,000,000 tons when the extensions now in hand are completed. The only weak link in our chain of manufacture is the absence of native magnesite suitable for bricks for basic steel furnace hearths. The high silica sands, formerly imported for use in acid steel furnaces, are now being found available in our own country.

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SCREWING TACKLE MANUFACTURERS' ASSOCIATION.—A meeting of representative screwing tackle manufacturers was held at the Queen's Hotel, Birmingham, on Thursday, the 17th inst., when it was unanimously decided to form a "Screwing Tackle Manufacturers' Association" to look after the interests of the screwing-tackle industry. Any screwing-tackle manufacturer who is interested in the association is invited to communicate with the Coventry Ordnance Works, Limited, Coventry, who are temporarily carrying out the secretarial work until the Executive Committee has been duly constituted.

## THE LATE MR. JOSIAH RICHARD PERRETT.

Many will share our regret on learning of the death, on the 21st inst., at Torquay, of Mr. Josiah Richard Perrett, who, for so many years, was an active agent in the development of warship design in this country, particularly at Elswick. He had retired for some years and had returned to Torquay, where, at Dr. Froude's tank he had done such splendid work in the earlier days of experimental research into the resistance of ships, having as a fellow worker in those years the late Mr. William Denny, of Dumbarton. From this time onwards, Mr. Perrett, endowed with the scientific mind, exercised great influence on ship design.

He was born in February, 1848, at Corbridge-on-Tyne, and received his preliminary education at the Free School, Plymouth, from 1855 to 1862. From the latter year to 1873 he served as a pupil at H.M. Dockyard, Devonport, entering later the Royal School of Naval Architecture, the Chatham Dockyard and the Admiralty. From 1873 to 1885, Mr. Perrett assisted the late Mr. William Froude at the experimental works, Torquay, carrying out experiments with ship models and models of screw propellers, also rolling experiments with His Majesty's ships Perseus and Greyhound, and dynamometer trials with other ships. From 1885 to 1887, Mr. Perrett was Assistant Constructor of the First Class at the Admiralty, and in the latter year he joined the Elswick shipyard of Sir W. G. Armstrong, Whitworth and Co., Limited, as first assistant to Sir Philip Watts; on the latter taking up his position as Director of Naval Construction to the Admiralty, Mr. Perrett was appointed General Manager and Chief Constructor to the Elswick shipyard.

To review Mr. Perrett's work as a naval architect would mean largely to record the work done at Elswick, not only for the British Navy but for many foreign powers, notably, those of South America, Italy, and Japan. He was invariably successful, alike in achieving propulsive efficiency and high offensive power. Indeed, the ships with the design of which he was identified marked the way towards that increase in gun power which found its culminating point in the Dreadnought designs immediately preceding the war. His cruisers were particularly notable for their high speed in association with their power of attack, and there can be no doubt that he was, from this point of view, one of the great exemplars in connection with warship design. Mr. Perrett was of a retiring disposition, and did not court publicity or distinction, so that the decorations which were conferred upon him by Japan, Italy and Turkey, for his warship designs for these respective countries, were all the more merited. He took little part in the discussions at the technical institutions, and it was only with the greatest persuasion that he was induced to write a paper for the last Newcastle meeting of the Institution of Naval Architects. He was, however, ready with advice, especially to the young naval architect, and his shrewdness, associated with a large theoretical and practical experience, together with his guiding principle of extreme accuracy, have had great influence on many of those young men. He was exceedingly kindly disposed to all, and was a charming companion, with a rare fund of quiet humour, so that his loss will be widely regretted, and his wife and family may be assured of the sympathy of many friends.

Mica Schist for Furnace Lining.—Mica schist, consisting essentially of mica and quartz with other minerals, is a very common metamorphic work, but too soft and too prone to foliate—moreover, too unattractive in appearance—to find much use as structural stone or paving stone. It has not answered as material for flagstones either. The schist is useful, however, as furnace lining, because it withstands high temperatures, and it can easily be cut into blocks of suitable shape. In Eastern Pennsylvania 39,925 short tons of mica schists were mined in 1917, 20 per cent. more than in 1916; the increase in value amounted to 82 per cent.

France's Share in the Progress of Science.—On Tuesday last, Professor Henri L. Joly, Professor of physical and natural science at the Institut Français, 1, Connaught Place, W., which is affiliated to the Lycée Français of Paris, gave the first of a course of three lectures on France's Share in the Progress of Science, at University College, Gower Street. Dealing in the first very interesting lecture with mathematics, astronomy and physics, Professor Joly briefly reviewed the work of the long series of eminent French scientists, more particularly from the sixteenth century to our days. He told many a characteristic story of many a man, like Arago, Regnault, Mascart, Poincaré, whom he had himself known as teachers, and we venture to think that he would please his audience still more if in future lectures he concentrated his attention more upon scientific men who need not necessarily be popular favourites, but whose work justifies prominence in this connection. The two other lectures, on chemistry and natural science and on biology and medical science are to be delivered on the Tuesdays, October 29 and November 5, at 5 p.m. The lectures are open to the public without fee or ticket.

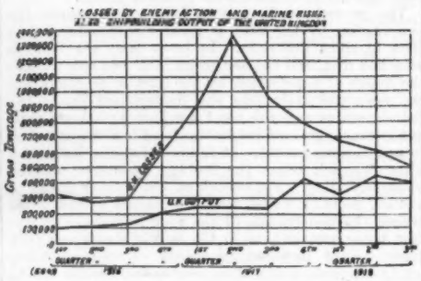
## THE SUBMARINE MENACE.

Statements made officially both in America and France have stated that there has been a great increase in the activity of the enemy submarines, but that this greater activity has not met with proportionate success. This latter conclusion is confirmed by the Admiralty returns of the shipping losses from all causes during the past quarter. The figures are as follow:—

*Losses from Enemy Action and Marine Risks (Gross Tons)*

| Period. | British. | | Allied and Neutral. | | Total. | |
|---|---|---|---|---|---|---|
| | Month. | Quarter. | Month. | Quarter. | Month. | Quarter. |
| 1917 | | | | | | |
| Sept. | 209,212 | 952,938 | 159,949 | 541,535 | 369,161 | 1,494,473 |
| Oct. | 289,973 | | 197,364 | | 487,337 | |
| Nov. | 196,560 | | 136,883 | | 333,443 | |
| Dec. | 296,356 | 782,889 | 155,707 | 489,954 | 452,063 | 1,272,843 |
| 1918 | | | | | | |
| Jan. | 218,621 | | 138,887 | | 357,508 | |
| Feb. | 254,303 | | 133,646* | | 387,949* | |
| Mar. | 224,666 | 697,590 | 176,797 | 449,330* | 401,463 | 1,146,920* |
| April | 233,169* | | 85,412* | | 318,581* | |
| May | 231,787* | | 133,203 | | 364,990* | |
| June | 165,550* | 630,506* | 114,249* | 332,864* | 279,799* | 963,370* |
| July | 182,524 | | 142,250* | | 324,774* | |
| Aug. | 176,434* | | 151,738* | | 328,172* | |
| Sept. | 151,593 | 510,551 | 88,007 | 381,995 | 239,600 | 892,546 |

* Adjusted.




The amount of merchant tonnage sunk by enemy action (excluding marine risk) during September was lower than any month since August, 1916, being considerably below June, the previous lowest month of this year, and also below the monthly average of 1916.

The tonnage of steamships of 500 gross tons and over entering and clearing United Kingdom ports from and to ports overseas was as under:—

| Period. 1918. | Gross Tons. |
|---|---|
| April | 7,040,309 |
| May | 7,777,843 |
| June | 7,430,386 |
| July | 7,718,898 |
| August | 8,158,639 |
| September | 7,515,061 |

*Note.*—This statement embraces all United Kingdom seaborne traffic other than coastwise and cross-Channel.

Data as to the world's output of shipping during the past quarter are not available, but the United Kingdom completed and put into service 411,395 tons. There is thus still a large margin between our output and our losses, but as the annexed diagram shows the two are steadily converging.

## "COAL SAVING BY SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

To the Editor of Engineering.

Sir,—I have followed with great interest the correspondence on the above subject which has appeared in your columns from time to time. Some very valuable information has been given, but one would like to hear the remarks on Mr. Brownlie's tests from the chief engineer of one or two of the boiler insurance societies, viz., Mr. Longridge, of the British Engine and Boiler Insurance Company, and Mr. Stromeyer of the Manchester Steam Users' Association: both these gentlemen are well-known authorities on steam boiler plant, and it would be a great national benefit if either of these gentlemen could see their way to express their views on this subject.

Yours faithfully,
"Engineer."

October 17, 1918.

To the Editor of Engineering.

Sir,—Will you kindly allow me a little more of your valuable space. Firstly, to express regret, if I in my rough Yorkshire way have hurt the feelings of any of your correspondents. My object in writing at all was to signify my appreciation of the excellent contribution of Mr. Brownlie. Secondly, to try and bring your correspondents to the point, viz., "Coal Saving by Scientific Control of Steam Boiler Plants." I presume that is the one, and only issue. I do not see why transport matters should enter into the discussion. I am glad that Mr. Anderson will admit "That a correctly-designed plant and a few scientific tell-tales are an advantage, but even then too much is left to the stoker, &c., &c." Here I again differ; my experience with stokers, extending over twenty-five years, is that if you make it easier for him, he will do the correct thing. What can a stoker or anyone else do beyond seeing the boiler seatings airtight, kept clean inside and out, fire correctly—now none of the above conditions can be complied with, except the cleaning, without a $CO_2$ indicator, which gives an indication if excess air be present; then the sensible man looks round to find it, whether leakage through the fire or through the seatings. In writing my last letter to you, Sir, I did not set out to try and teach any of your correspondents their business. My only object was to state in simple language the only way successfully to save coal. The question is raised by Mr. Anderson of design of the Lancashire boiler, and he compares it with the water tube, the latter is an impossible boiler for collieries, dye-works, &c., where large reserves of steam are required. I have nothing further to add to my last letter, only to hope in the near future, that we shall see gauges fixed up alongside the steam gauge, showing the quality of combustion, and the exit temperature of the flue gases for the present. Until some superman brings forth such instruments we must be content with what the market has to offer. Every boiler should be fitted with a reliable $CO_2$ indicator, and stokers should be trained to use them. There is one, a very simple, accurate, and reliable instrument, on the market. The reason I withhold my name is because I am such an unknown man, it would not convey anything to your readers.

Yours faithfully,
"Get a Move On."

## THE ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN.

To the Editor of Engineering.

Sir,—Members of the Association of Engineering and Shipbuilding Draughtsmen will ever remember the service that you rendered them in allowing the various letters, contributed by draughtsmen, to be published in the columns of your interesting and valuable journal at the time when we were considering registration under the Trades Union Act.

This is almost an accomplished fact, and it was largely due to the various views that were expressed at that time that resulted in a vote of 95 per cent. in favour of such a course being followed.

There is also another question which I think should at once receive the careful consideration of our members, that is the question of amalgamation of all the engineering unions. It is well known that a committee on which our association is represented, is sitting at the present time to draw up such a scheme, and I hope that success will attend their efforts. That such a thing should be speedily brought about is to my mind absolutely essential, if we are to make progress. With a little give and take and goodwill such a thing could easily be brought about, giving to each its own craft management, always providing that it does not prejudice the smooth working of the whole, and a supreme governing executive composed of delegates representing the various crafts.

We are witnessing the engineering industry being formed into two or three large trusts, and it is high time we realise our position before it is too late. I feel convinced that for the good of the nation, Joint Industrial Councils will have to be formed as outlined in the Whitley report, and we shall find that the employers' federations will have a united policy, whether it be for good or evil. Unless we are welded together, both brain and manual worker, we shall find the usual red herrings drawn across our path in order to divide and thus spoil the good work which I honestly believe the Whitley Committee had in view.

This letter is intended more particularly for the members of our own organisation, who are all fully aware that up to the present time we have been unable to obtain recognition by the various employers' federations, and I feel sure that if we do not amalgamate with the men in the shops we shall have a long way to travel before the desired haven is reached.

As members know, the annual meeting of the Manchester branch is to be held on November 2, 1918, it would be as well to raise this important question so that our officials will know the opinions of our members.

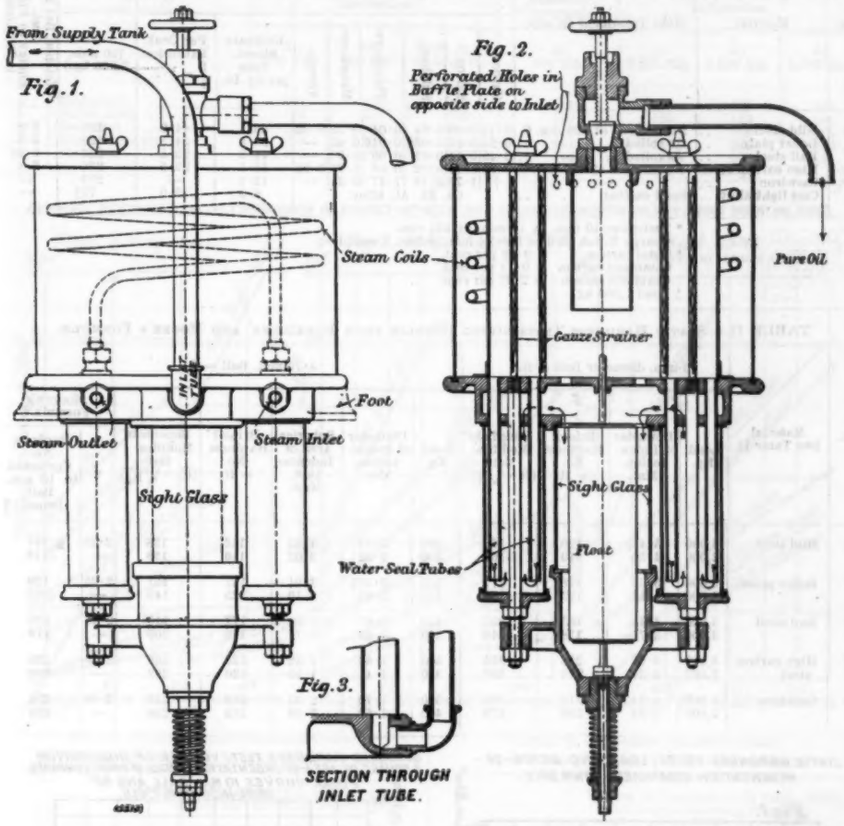
In conclusion, amalgamation also raises such subjects as affiliation to the Labour Party, which I understand is down upon the agenda under the heading of special motions. Trusting that other members will give an expression of their views.

Manchester. "Senior Draughtsman."

The late Mr. James Foyell Lovelock Crossland.—We regret to have to announce the death, which occurred on the 21st inst., of Mr. J. F. L. Crossland, late chief engineer to the Vulcan Boiler Insurance Company, Limited. Mr. Crossland was born in March, 1840; he served an apprenticeship in the shops and drawing offices of the Gorton Railway Works, from 1855 to 1860. He was then for one year draughtsman with Messrs. D. Adamson and Co., Newton Moor and Hyde, near Manchester; he then, from 1861 to 1864, practised on his own account as a consulting engineer, designing, supplying and erecting engines, boilers and mill gearing. Mr. Crossland was for twenty-four years, down to 1888, principal assistant engineer to the Boiler Insurance and Steam Power Company, Limited, of which he became later the chief engineer. He was elected a member of the Institution of Mechanical Engineers in 1881, of the Civil Engineers in 1894, and of the Electrical Engineers in 1900.

# THE SANDS OIL SEPARATOR.

## CONSTRUCTED BY MESSRS. J. H. CARRUTHERS AND CO., LIMITED, POLMADIE.




We illustrate in Figs. 1 to 3 on the present page the Sands' oil separator, manufactured by Messrs. J. H. Carruthers and Co., Limited, engineers, Polmadie Iron Works, Hamilton-street, Polmadie, Glasgow. They state, with reference to this apparatus, that oil used for forced lubrication is subject to contamination by water in course of time, a very small quantity of water being sufficient to destroy all lubricating qualities. The result is a very material increase in cost, which is a particularly important item at the present time, in view of the high price of oil and the necessity for saving the tonnage involved in its carriage to this country. In some cases, an attempt at the recovery of oil is made by storing it for some time and allowing the water to separate by gravity, but this is a slow process and not very efficient.

The apparatus illustrated effects a complete separation of the two fluids continuously and in a highly efficient manner. The contaminated oil flows in a steady stream into the top of the apparatus, and after being raised by a steam coil to a suitable temperature, passes over a series of screens which have the property of resisting the passage of water, but being freely permeable to the oil. The oil flows away quite free from water, whilst the latter is automatically discharged by a trap at the bottom of the apparatus, governed by a float, shown in Fig. 2. The apparatus is capable of treating 15 gallons per hour; it has been in use for a considerable time and gives excellent results.

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BRITISH FIRMS AND AGENCIES IN BAHIA.—According to *The Board of Trade Journal*, the British Consul at Bahia points out that a great number of Brazilians, Portuguese and neutrals are representing British firms in his districts, and that the number is steadily growing. In addition, he points out that the number of British firms trading in his districts has been for a number of years decreasing. Before the war some of our best agencies were in the hands of Germans, and when the war came these agencies were transferred to Brazilians. H.M. Minister at Rio de Janeiro also states that the main reason for the steady decline of British firms, and the steady shrinkage of the British colony in Bahia, is the tendency shown by our traders to liquidate their business when they consider that there is no necessity for them to continue in business any longer. He furnishes a list of 30 British firms which have disappeared from Bahia during the last fifty years.

## VALUE OF THE INDENTATION METHOD IN THE DETERMINATION OF HARDNESS.*

By R. G. C. BATSON, of the National Physical Laboratory, Associate Member.

*Summary.*—The paper deals with :—

(1) The determination of hardness by means of the indentation produced by a static load.

(2) The determination of hardness by means of the indentation produced by the impact of a ball or cone.

(A) By means of (1) it is shown that a hardness number can be obtained :—

(*a*) Independent of the diameter of the ball, by using Moore's formula based on Meyer's conclusion that "the mean pressure per unit area is constant for a given angle of impression whatever the diameter of the ball."

(*b*) Independent of the load, by calculating it from the slope of the "load-depth of indentation" diagram when this diagram becomes straight. [Two impressions at different loads are sufficient, provided they are on the straight part of the diagram.]

(B) In method (2) two forms of indenting tool have been employed; Martel used a point, and Roos used a 10 mm. ball. The methods of calculating the dynamic hardness number given by both Martel and Roos are in agreement for ordinary indentations, using the ball-indenting tool, but while the formula suggested by Martel applies to a ball as well as to a cone, that suggested by Roos does not apply to both forms of tool. It is shown that, within the limits of the experiments :—

(*a*) Energy of blow is proportional to volume of indentation for cone and ball indenting tools, and the dynamic hardness number suggested is (as applied by Martel to cone)—

$$= \frac{\text{Energy of blow in kgm.}}{\text{Volume of indentation in cm.}^3}$$

(*b*) Energy of blow is proportional to square of spherical area of indentation for ball indenting tool only (Roos).

(*c*) Volume of indentation (and therefore dynamic hardness number) is approximately independent of form of indenting tool (cone, 10 mm. ball and 4·76 mm. ball).

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The indentation method for determining hardness is applied by producing the indentation either by a static load or by a blow. The two methods involve different considerations and, although testing machines are supplied using both principles, the way in which corresponding hardness numbers should be calculated, and conversion factors used where standard conditions are departed from, does not seem to be generally understood.

### (A) STATIC HARDNESS (INDENTATION) TEST.

This method of test is the one commonly employed in practice, and various ways of making the indentation have been employed either by pressing two pieces (shaped in a given form) of the material together or by pressing a harder material into the one under test.

Owing to the difficulty of applying the former method in practice, the latter form of test is now universally adopted, and the indenting tool usually employed is a ball of 10 mm. diameter. Several experimenters have pointed out, and it is now generally known, that the ball hardness number, calculated by dividing the spherical area of the indentation into the load, varies with (*a*) the size of ball used; and (*b*) the load applied.

In consequence of this variation, a standard ball of 10 mm. and a fixed load of 3,000 kg. have been adopted for the test. It sometimes happens (for example, with light alloys or very small test-pieces) that it is not convenient to use either this diameter of ball or 3,000 kg. load, and conversion factors are required.

(*a*) *Variation with Size of Ball.*—Benedicks,* of Upsala, investigated this variation, and gave the rule that for any given metal a constant product would result if the Brinell number, obtained by dividing the spherical area of indentation in square millimetres into the load in kilogrammes was multiplied by the fifth root of the radius of the ball. It has been found by the author, confirming some work by H. Moore,† that by applying this method a constant number is not obtained, Table 2, page 476.

Meyer,‡ in some published results in 1908, showed (1) that $P = a\,d^n$ where $n$ is a constant depending on the material and $a$ is a constant for a given material and given ball diameter; (2) that the mean pressure per unit area $\left(\frac{4P}{\pi d^2}\right)$ is constant for a given angle of impression whatever the diameter of the ball.

H. Moore† suggests that the standard angle chosen should give the diameter of impression equal to half the diameter of the ball. The hardness number then, according to Moore $= \frac{4P}{\pi d^2}$ where $d = \frac{1}{2}D$, D being the diameter of the ball in millimetres, and P the load in kilogrammes.

Moore pointed out that in practice the hardness number can always be obtained from two impressions, using the same diameter of ball and applying the formula :

$$\text{Hardness No.} = \frac{16\,PD^{n-2}}{\pi\,(2d)^n},$$

where $n$ is a constant, between 2 and 2·5, depending on the material, and calculated from :

$$n = \frac{\log P_1 - \log P}{\log d_1 - \log d},$$

where P and $d$, and $P_1$, $d_1$ are the corresponding loads and diameters of indentation. As the above formula for hardness number is calculated using the area of the indentation $\frac{\pi d^2}{4}$, and not the spherical area of indentation, the corresponding Brinell number is :

$$\frac{1}{1{\cdot}0718} \times \frac{16\,PD^{n-2}}{\pi\,(2d)^n}.$$

For the majority of materials tested $n$ is known with sufficient accuracy, in which case the Brinell hardness number with any size ball can be calculated from one impression.

Moore made numerous tests and has published results showing that the hardness numbers obtained by using different diameters of ball are in agreement, if the above method of calculating the hardness number is used.

A series of tests were made by the author on (*a*) mild steel; (*b*) boiler plate; (*c*) rail steel; (*d*) high carbon steel; and (*e*) cast-iron, full particulars of which are given in Table 1, page 476.

10 mm. and 4·76 mm. diameter balls were used for the tests, and the results given in Table 2, page 476, show :—

(1) That Benedicks' modification of the Brinell hardness number does not give a constant figure for the same material.

(2) That Moore's formula gives Brinell hardness numbers for the 4·76-mm. ball, which are in close agreement with those using the standard ball and load (10 mm. and 3,000 kg.).

This is a confirmation of Moore's conclusions.

(*b*) *Variation with Load.*—In order to investigate this variation, tests have been made on the materials previously used, Table I, page 476, with the apparatus designed by Martens and fully described in a paper by Martens and Heyn.§ This apparatus measures the depth of the indentation by means of three little steel rods which settle on the surface of the specimen. These rods, by means of intermediate plates and pistons, are connected to a steel piston which is ground mercury tight into the cylinder. Mercury fills the space in this cylinder and in part of a capillary attached to it. The ball is

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* Paper read before the Institution of Mechanical Engineers, Friday, October 18, 1918.

* C. Benedicks, "Recherches Physiques et Physico-chimiques sur l'acier au Carbone," Upsala, 1904.

† H. Moore, "Investigations on the Brinell Method of Determining Hardness," Proc. Inc. Ass. of Testing Material, 1909.

‡ E. Meyer, *Zeitschrift des Vereines deutscher Ingenieure*, 1908, page 645.

§ Martens and Heyn, "A Simplified Ball Test Device," Proc. Int. Ass. of Test. Materials, 1909, also *Zeits. d. Vereines deutsch. Ing.*, 1908.

fixed to the machine between the three little steel rods so that when the pressure is applied and the indentation produced, these rods, together with the parts attached to them, are lifted, and the mercury raised in the capillary by an amount which is read off on the scale. This amount corresponds to the depth of the indentation. The machine was designed for use with a 5-mm. ball, and the author fitted a special adaptor to it to take the standard 10-mm. ball which was used in the tests.

The machine was specially suitable for studying the variations of hardness numbers with load as the depth of indentation could be recorded at various loads on the same ball impression. Load-depth diagrams are given in Figs. 1 and 2, annexed, and show that after an initial load, which depends on the material the rate of increase of depth (and therefore the spherical area of indentation) with load is constant. It follows, therefore, that owing to the initial curved part of the diagram, the larger loads give higher Brinell hardness numbers when calculated in the usual way, and this is in agreement with the results of other experimenters.

It is evident that, in order to obtain hardness numbers independent of the load, they should be calculated from the slopes of the straight parts of the diagrams. Values of the hardness numbers for the materials used calculated from the depth of the indentation together with those obtained by the standard Brinell method using a Buckton testing machine are given in Table 3, page 477.

The results show :—

(1) Hardness tests made in the usual way vary with the load employed.

(2) Hardness numbers calculated from the depth are higher than those calculated from the diameter. This would be expected because the depth measurement does not take into account the pushing up of the material at the edges of the indentation.

(3) The hardness numbers obtained on the Martens machine, when the final diameter of the impression is measured, are in agreement with those obtained by using a Buckton testing machine, except that the value for the boiler plate in the former instance is slightly high.

(4) Hardness numbers obtained from the slopes of the curves give reliable indications of the static indentation hardness and are independent of the load. So that values can, by this means, be obtained on light alloys which are comparable with those given by hard steels, as with soft materials it is very often impossible to obtain satisfactory results by applying loads exceeding 1,500 kg.

[Two impressions at different loads are sufficient for calculating this value provided that the material is uniform, and that, at these loads, the diagram is straight.]

### (B) Dynamic Hardness (Indentation) Test.

A dynamic hardness test was propounded by Martel* in 1895. He used a pyramidal point as the indenting tool and produced the indentation by the fall of a ram on to the tool. Martel found :—

(a) That the work of the falling ram was proportional to the volume of the indent, and he therefore expressed hardness as the work required to produce unit volume of indention.

(b) That for equal energies of blow the volume of indentation was nearly the same, when using indenting tools of slightly different form.

Brinell† in 1906 described some indentation hardness experiments, made statically and by impact, using a 10 mm. ball as an indenting tool, and quoted some results by J. O. Roos. Roos showed that, with a 10-mm. ball, $\frac{A^2}{E}$ is constant where A = the spherical area of indentation and E = the energy of blow.

There are thus two alternative methods suggested of expressing impact or dynamic hardness :—

(1) Where the energy of blow varies as (area)$^2$.

(2) Where the energy of blow varies as volume of indentation.

If h = depth of the indentation.
D = diameter of the ball.

Volume of indentation = $\frac{\pi}{3} h^2 (\frac{1}{2} D - h)$.

Square of spherical area of indentation = $(\pi D h)^2$.

Fig. 3 shows volume of indentation plotted against square of spherical area of indentation for the same values of h and using a 10 mm. ball. The line is seen to be straight, and this relationship holds up to a depth of indentation of 0·1 mm. corresponding to a diameter of indentation of 6 mm. Thus if the energy of blow is proportional to the volume of the indent it will also be proportional to the square of the spherical area of indentation; so that it follows from geometrical considerations that both the methods of expressing dynamic hardness used by Martel and Roos must be in agreement, for ordinary indentations, when a ball indenting tool is used.

Considering the case of the cone with 90 deg. vertical angle, if h = depth of indentation.

Volume of indentation = $\frac{\pi}{3} h^3$, i.e., varies as $h^3$.

Square of surface area of indentation = $2 \pi^2 h^4$; i.e., varies as $h^4$.

A "volume of indentation—square of area of indentation" curve is given for the 90-deg. cone in Fig. 3, and the line is seen to be curved. It therefore follows that, for the cone, if the energy of blow is proportional to the volume of indentation it will not be proportional to the square of the area of indentation or *vice versa*.

As Martel used a point, and Brinell and Roos a ball, further work on dynamic hardness using both forms of indenting tool seemed therefore to be desirable. A series of tests have been made, using various materials in order to determine :—

(a) Whether the energy of blow is proportional to the volume of the indent or square of the area of the indent for ball and cone.

(b) If the volume of indentation is the same with indenting tool of different form.

*Testing Machine.*—The machine adapted for the testing was primarily designed and used for impact tests on road stones, and consisted of a heavy bed supporting two guide rod for the hammer. The hammer was raised mechanically by a projection fixed to a chain driven from the shop shafting, and was released by an adjustable stop attached to the guide rods. The height of drop could be varied from 0 cm. to 90 cm. A new hammer was made for the machine with provision for various forms of indenting tools which were fixed to the hammer and descended with it. The weight of the complete hammer was 1·76 kg. The forms of indenting tools used were :—

(1) 10 mm. diameter hardened-steel ball.
(2) 4·76 mm. diameter hardened-steel ball.
(3) Hardened steel cone with vertical angle of 90 deg.

The materials tested, full particulars of which are given in Table I, above, were the same as those used for static hardness tests, namely : (a) Mild steel ; (b) boiler plate ; (c) rail steel ; (d) high carbon steel ; (e) cast-iron ; and (f) cast light alloy.

*Method of Test.*—The materials, in the forms of bars approximately 1½ in. square and 4 in. to 6 in. long, were machined parallel and polished on one side. They were held firmly on the bed of the testing machine while the blow was delivered, and with the ball indenting tools, moved immediately after the initial blow and indentations also obtained by the rebound of the hammer. With the cone-indenting tool, the tool centred itself in the indentation on the rebound so that the volume of material displaced could be measured directly. With the ball-indenting tools the rebounds of the hammer, not being in exactly the same place as the original indents, caused confused impressions, so that when these forms of tool were employed the indentations were obtained without the rebounds and the volumes calculated from

TABLE I.—Particulars of Materials.

| No. | Material. | Heat Treatment (if any). | Chemical Analyses. Per Cent. Carbon. | Silicon. | Sulphur. | Phosphorus. | Manganese. | Arsenic. | Tensile Test. Ultimate Stress. Tons per Sq. In. | Per Cent. Extension. $\frac{L}{a} = 3{\cdot}7$. | Static Brinell Test. (10 mm. 3,000 kg.) | Notched Bar Impact Test. Energy to Fracture in kgm./cm.$^2$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | Mild steel .. | Normalised at 900 deg. C. | 0·19 | 0·03 | 0·04 | 0·04 | 0·59 | 0·02 | 26·1 | 44·0 | 120 | 8·8 |
| b | Boiler plate .. | As rolled .. .. .. | 0·25 | 0·06 | 0·032 | 0·046 | 0·65 | — | 28·9 | 34·5 | 128 | 5·2 |
| c | Rail steel .. | As rolled .. .. .. | 0·45 | 0·11 | 0·05 | 0·05 | 0·97 | — | 44·3 | 22·5 | 183 | 0·66 |
| d | High carbon steel | Normalised at 800 deg. C. | 0·65 | 0·14 | 0·02 | 0·03 | 0·71 | 0·02 | 53·1 | 22·5 | 236 | 2·1 |
| e | Cast-iron .. | — | † | 1·76 | 0·13 | 1·47 | 0·34 | — | 12·1 | — | 212 | — |
| f | Cast light alloy .. | Sand casting .. .. | Cu. Zn. Al. Alloy. | | | | | | 8·9 | 3·0 | 72‡ | — |

* Test-piece 10 mm. by 10 mm. by 53½ mm.
Charpy Notch (drilled hole) ¼ mm. radius, 5 mm. deep.
† Total carbon = 0·03 per cent.
Combined carbon = 0·71 per cent.
Graphitic carbon = 2·32 per cent.
‡ Load 1,000 kg.

TABLE II.—Static Hardness Tests giving Results from Benedicks' and Moore's Formulæ.

| No. | Material (see Table I). | 10-mm. diameter Ball = R. Load. Kg. | Diameter of Indentation. Mm. | Brinell Hardness No. = H. | Benedicks' Modification. ($H \times \sqrt[4]{R}$). | 4·76-mm. Ball = $R_1$. Load Kg. | Diameter of Indentation. Mm. | Spherical Area of Indentation. Mm$^2$. | Brinell Hardness No. = $H_1$. | Benedicks' Modification. ($H_1 \times \sqrt[4]{R_1}$). | Moore's Formula. s. | Hardness No. Corrected. to 10 mm. Ball (Brinell). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | Mild steel .. | 3,000 | 5·41$_5$ | 120 | 166 | 500 | 2·27 | 4·32 | 116 | 138 | 2·25 | 117 |
| | | 2,000 | 4·50 | 119 | 164 | 350 | 1·92 | 3·02 | 116 | 138 | — | 119 |
| b | Boiler plate | 3,000 | 5·25 | 128 | 177 | 500 | 2·175 | 3·94 | 127 | 151 | 2·25 | 129 |
| | | 2,000 | 4·42$_5$ | 123 | 170 | 400 | 1·97 | 3·19 | 125 | 149 | — | 129 |
| c | Rail steel .. | 3,000 | 4·45$_5$ | 183 | 253 | 400 | 1·67 | 2·26 | 177 | 210 | 2·14 | 179 |
| | | 2,000 | 3·71$_5$ | 178 | 246 | 300 | 1·46 | 1·71 | 176 | 209 | — | 179 |
| d | High carbon steel | 3,000 | 3·94 | 236 | 326 | 500 | 1·66 | 2·22 | 225 | 268 | 2·25 | 235 |
| | | 2,000 | 3·34$_5$ | 222 | 306 | 350 | 1·41 | 1·59 | 220 | 262 | — | 238 |
| e | Cast-iron .. | 3,000 | 4·14 | 213 | 294 | 500 | 1·70 | 2·35 | 213 | 253 | 2·00 | 205 |
| | | 2,000 | 3·51 | 200 | 276 | 400 | 1·52 | 1·86 | 215 | 256 | — | 206 |

STATIC HARDNESS TESTS; LOAD AND DEPTH-OF-INDENTATION COMPARED. 10 MM. BALL.

Fig. 1.

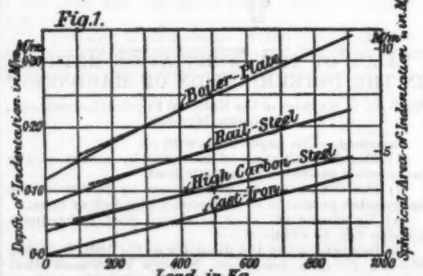
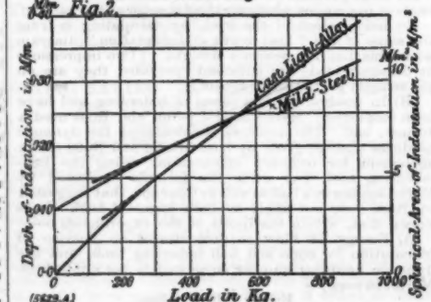


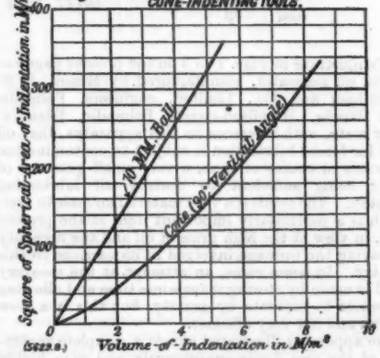

Fig. 2.




(5229.4)

DYNAMIC HARDNESS TEST; VOLUME-OF-INDENTATION & SQUARE OF AREA-OF-INDENTATION (SURFACE OF INDENT) COMPARED.

Fig. 3. CURVES 10 m/m. BALL AND 90° CONE-INDENTING TOOLS.




(5229.5)

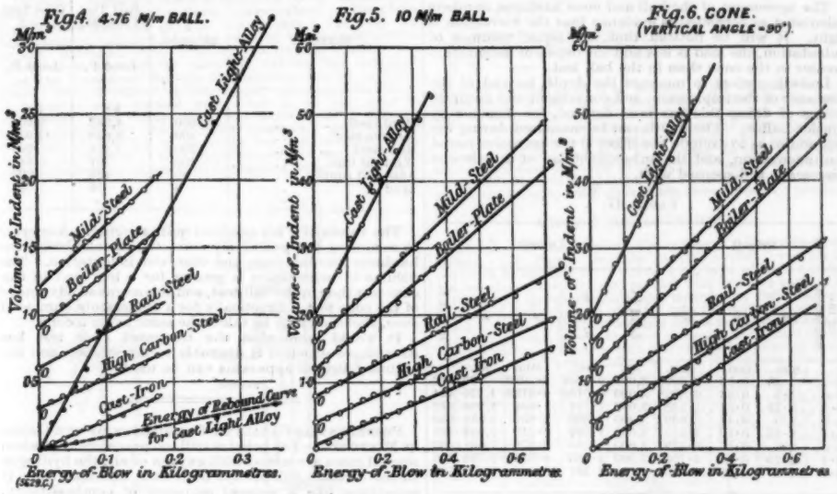
* Martel, "Commission des Méthodes d'Essais des Materiaux de Construction," Paris, 1895, Sect. A, page 261; also Unwin, "Testing of Materials of Construction," London, 1899, page 46.

† "Report on Hardness Tests," 1906, Congress of International Association of Testing Materials; also Engineering, November 9, 1906, page 638.

TABLE III.—STATIC HARDNESS NOS. USING 10 MM. DIAM. BALL.

| No. | Material (see Table I). | Hardness Number by Martens' Apparatus. | | | Hardness Number by Buckton Testing Machine. | | | |
|---|---|---|---|---|---|---|---|---|
| | | Calculated from Depth of Indentation. | | | Calculated from Diameter of Indentation. | From Diameter of Indentation. | | |
| | | At 500 Kg. | At 900 Kg. | From Slope of Diagram. | At 900 Kg. | At 3,000 Kg. | At 2,000 Kg. | At 1,000 Kg. |
| *a* | Mild steel .. .. .. | 121 | 126 | 136 | 111 | 120 | 119 | 106 |
| *b* | Boiler plate .. .. .. | 126 | 131 | 140 | 120 | 128 | 123 | 108 |
| *c* | Rail steel .. .. .. | 187 | 197 | 216 | 174 | 183 | 178 | 174 |
| *d* | High-carbon steel .. .. | 249 | 257 | 269 | 207 | 236 | 222 | 206 |
| *e* | Cast-iron .. .. .. | 235 | 235 | 235 | 190 | 215 | 200 | 188 |

DYNAMIC HARDNESS TESTS; COMPARISON OF ENERGY-OF-BLOW WITH VOLUME-OF-INDENTATION, WITH VARIOUS INDENTING TOOLS.




(5279.C)

TABLE IV.—*Dynamic Hardness Tests.*

(1) Indenting tool = 4·76 mm. diameter ball.

| Energy of Blow in Kgm. | Volume of Indentation in cubic millimetres (not including rebound). | | | | | |
|---|---|---|---|---|---|---|
| | *a.* Mild Steel. | *b.* Boiler Plate. | *c.* Rail Steel. | *d.* High Carbon Steel. | *e.* Cast-Iron. | *f.* Cast Light Alloy. |
| 0·018 | 0·11 | 0·09 | — | 0·05 | 0·04 | 0·18 |
| 0·035 | 0·18 | 0·17 | 0·11 | 0·09 | 0·07 | 0·29 |
| 0·053 | 0·29 | 0·23 | — | 0·13 | 0·11 | 0·47 |
| 0·070 | 0·34 | 0·29 | 0·18 | 0·16 | 0·15 | 0·59 |
| 0·088 | 0·39 | 0·36 | — | 0·20 | 0·19 | 0·87 |
| 0·105 | 0·50 | 0·45 | 0·30 | 0·23 | 0·23 | 0·92 |
| 0·123 | 0·57 | 0·51 | — | 0·29 | 0·25 | 1·12 |
| 0·140 | 0·64 | 0·60 | 0·38 | 0·31 | 0·31 | 1·27 |
| 0·158 | 0·73 | 0·64 | — | 0·34 | 0·33 | 1·46 |
| 0·176 | 0·82 | 0·72 | 0·46 | 0·39 | 0·38 | 1·61 |
| 0·264 | — | — | — | — | — | 2·43 |
| 0·352 | — | — | — | — | — | 3·21 |
| *Average dynamic hardnessnumber from curve .. | 213 | 241 | 371 | 444 | 466 | 107 |

Particulars of materials are given in Table I.

* Dynamic hardness number =

$$\frac{\text{Energy of blow in kilogrammetres}}{\text{Volume of indentation in cubic centimetres.}}$$

their diameters. In order to compare total volumes displaced, the indentations given by the rebounds were also measured, and, for such comparisons added to the other figures.

The indentations were measured on two diameters at right angles by a measuring microscope, and the volumes of the indentations calculated from the means of the readings.

The results of the tests are given in Tables IV, V and VI, above, and the figures for energy of blow and volume of indentation are plotted in Figs. 4, 5 and 6, also above.

An examination of the curves shows that all the points lie on straight lines, proving that for the three forms of indenting tool selected, and the range of energy of blow used the volume of the indentation is proportional to the energy of blow.

The energy of blow is therefore proportional to the square of the spherical area of indentation with the ball-indenting tools only, and not with the cone-indenting tool.

In order that the dynamic hardness number should apply to all three forms of indenting tool it was taken as being

$$= \frac{\text{Energy of blow in kilogrammetres}}{\text{Volume of indentation in cubic centimetres.}}$$

TABLE V.—*Dynamic Hardness Tests.*

(2) Indenting tool = 10-mm. diameter ball.

| Energy of Blow in Kgm. | Volume of Indentation in Cubic Millimetres (not including rebound). | | | | | |
|---|---|---|---|---|---|---|
| | *a.* Mild Steel.* | *b.* Boiler Plate. | *c.* Rail Steel. | *d.* High Carbon Steel. | *e.* Cast-Iron. | *f.* Cast Light Alloy. |
| 0·035 | 0·12 | 0·12 | 0·06 | 0·05 | 0·08 | 0·36 |
| 0·071 | 0·25 | 0·30 | 0·17 | 0·12 | 0·18 | 0·66 |
| 0·106 | 0·45 | 0·42 | 0·30 | 0·23 | 0·29 | 1·15 |
| 0·142 | 0·60 | 0·58 | 0·37 | 0·32 | 0·37 | 1·35 |
| 0·177 | 0·75 | 0·75 | 0·47 | 0·39 | 0·42 | 1·85 |
| 0·213 | 0·95 | 0·88 | 0·56 | 0·42 | 0·48 | 2·04 |
| 0·248 | 1·07 | 0·97 | 0·63 | 0·52 | 0·54 | 2·45 |
| 0·284 | 1·30 | 1·14 | 0·70 | 0·59 | 0·67 | 2·78 |
| 0·319 | 1·41 | 1·36 | — | 0·67 | 0·73 | 2·94 |
| 0·355 | 1·58 | 1·49 | 0·92 | 0·77 | — | 3·29 |
| 0·390 | — | — | 0·98 | — | 0·86 | — |
| 0·425 | — | — | — | — | 0·95 | — |
| 0·461 | — | — | 1·19 | — | — | — |
| 0·497 | — | — | — | — | 1·07 | — |
| 0·532 | — | — | 1·36 | — | — | — |
| 0·568 | — | — | — | — | 1·19 | — |
| 0·603 | — | — | 1·48 | — | — | — |
| 0·639 | — | — | — | — | 1·39 | — |
| 0·674 | — | — | 1·69 | — | — | — |
| 0·710 | 3·27 | 3·08 | — | 1·52 | 1·49 | — |
| 0·745 | — | — | 1·95 | — | — | — |
| †Average dynamic hardness number from curve .. | 212 | 236 | 394 | 467 | 494 | 107 |

* The energy of blow for this material with 10-mm. ball was 0·017 kgm. less than the value given.

† Dynamic hardness number =

$$\frac{\text{Energy of blow in kilogrammetres}}{\text{Volume of indentation in cubic centimetres}}$$

A summary of the dynamic hardness numbers taken from Tables IV, V and VI, for the three forms of tool, are given in Table VII, annexed.

It will be seen, from the table, that the dynamic hardness numbers calculated in this way are approximately independent of the form of indenting-tool.

*Auto-Punch Impact Hardness Tester.*—The method of calculating dynamic hardness numbers from the volumes of the indentations and energy of blow was applied to some results which had previously been obtained with a self-contained dynamic hardness tester manufactured by Messrs. Rudge Whitworth, Limited, Coventry, and called the auto-punch. This instrument takes the form of an automatic centre punch, the blow being applied by a compressed spring, the centre punch point being replaced by a ball $\frac{1}{16}$ in. diameter. The energy of blow was found to be approximately 0·032 kilogrammetres. The indentation made with the auto-punch includes that

TABLE VI.

(3) Indenting tool = cone with vertical angle of 90 deg.

| Energy of Blow in Kgm. | Volume of Indentation in Cubic Millimetres (including rebound). | | | | | |
|---|---|---|---|---|---|---|
| | *a.* Mild Steel. | *b.* Boiler Plate. | *c.* Rail Steel. | *d.* High-Carbon Steel. | *e.* Cast-Iron. | *f.* Cast Light Alloy. |
| 0·035 | 0·18 | 0 17 | 0·10 | 0·10 | 0·10 | 0·34 |
| 0·070 | 0·37 | 0·34 | 0·23 | 0·19 | 0·22 | 0·76 |
| 0·105 | 0·55 | 0·51 | 0·36 | 0·33 | 0·30 | 1·14 |
| 0·140 | 0·71 | 0·66 | 0·49 | 0·42 | 0·45 | 1·36 |
| 0·175 | 0·88 | 0·83 | 0·62 | 0·53 | 0·56 | 1·77 |
| 0·210 | 1·05 | 1·08 | 0·70 | 0·63 | 0·69 | 2·00 |
| 0·245 | 1·25 | 1·21 | 0·87 | 0·77 | 0·77 | 2·34 |
| 0·280 | 1·36 | 1·37 | 0·95 | 0·82 | 0·91 | 2·70 |
| 0·315 | 1·53 | 1·61 | 1·06 | 0·91 | 0·99 | 3·19 |
| 0·350 | 1·76 | 1·76 | — | 1·05 | 1·06 | 3·54 |
| 0·385 | — | — | 1·24 | — | 1·23 | — |
| 0·420 | — | — | 1·38 | — | — | — |
| 0·490 | — | — | 1·63 | — | — | — |
| 0·560 | — | — | 1·85 | — | — | — |
| 0·630 | — | — | 2·05 | — | — | — |
| 0·700 | 3·39 | 3·43 | 2·32 | 2·09 | — | — |
| *Average dynamic hardness number from curve .. | 201 | 202 | 299 | 331 | 314 | 100 |

The particulars of material are given in Table I.

* Dynamic hardness number =

$$\frac{\text{Energy of blow in kilogrammetres}}{\text{Volume of indentation in cubic centimetres}}$$

TABLE VII.—*Summary of Dynamic Hardness Numbers with Various Indenting Tools.*

| No. | Material (see Table I.) | Dynamic Hardness Numbers. | | | | |
|---|---|---|---|---|---|---|
| | | Cone-Indenting Tool. | 10-mm. Diam. Ball. | | 4.76-mm. Diam. Ball. | |
| | | (Including rebound) | (Including rebound) | (Not including rebound) | (Including rebound) | (Not including rebound) |
| *a* | Mild steel .. | 201 | 190 | 212 | 190 | 213 |
| *b* | Boiler plate .. | 202 | 210 | 236 | 210 | 241 |
| *c* | Rail steel .. | 299 | 310 | 394 | 300 | 371 |
| *d* | High carbon steel .. | 331 | 360 | 467 | 340 | 444 |
| *e* | Cast-iron .. | 314 | 370 | 494 | 350 | 466 |
| *f* | Cast light alloy | 100 | 100 | 106 | 100 | 107 |

TABLE VIII.—*Dynamic Hardness Numbers by the Use of the Auto-Punch.*

| No. | Material (see Table I). | Auto-Punch (Dynamic Hardness Number): | | | Dynamic Hardness Number (Direct Drop Machine N.P.L.) |
|---|---|---|---|---|---|
| | | Diameter of Indentation (Average of 3). | Volume of Indentation. | Dynamic Hardness Number. | |
| | | mm. | cub. mm. | | |
| *a* | Mild steel | 1·64 | $0{\cdot}15_3$ | 210 | 190 |
| *b* | Boiler plate | $1{\cdot}60_5$ | $0{\cdot}14_2$ | 225 | 210 |
| *c* | Rail steel | 1·58 | $0{\cdot}13_2$ | 240 | 305 |
| *d* | High carbon steel | $1{\cdot}42_5$ | $0{\cdot}08_7$ | 370 | 350 |
| *e* | Cast-iron | 1·49 | $0{\cdot}10_4$ | 310 | 360 |

due to the rebound, and as the indenting tool is a ball the indentations are usually slightly distorted owing to the rebound not being in exactly the same place as the original blow.

Table VIII, above, gives results of the tests, using this instrument and calculating the dynamic hardness numbers from the volume of the indentation and 0·032 kilogrammetres energy. The materials used were the same as for the tests previously described, and the average dynamic hardness numbers from these tests, using ball indenting tools, are given in the table for comparison.

The results obtained by the use of this instrument give dynamic hardness numbers approximately in agreement with the direct drop method. This agreement is very good when the small amount of energy and consequently small diameter of indentation are taken into consideration.

The author desires to express his thanks to Dr. T. E. Stanton, F.R.S., for the great interest he has taken in the experiments, and the valuable assistance he has given in the preparation of the paper.

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.—The City of Philadelphia, acting on the recommendation of the Franklin Institute, has awarded to Mr. Frank P. Fahy, consulting magnetic engineer, Hudson Terminal, New York, the John Scott Legacy Medal and Premium for the development of the Fahy Permeameter.

## THE LUDWIK HARDNESS TEST.*

By W. Cawthorne Unwin, LL.D., F.R.S., Past-President and Hon. Life Member.

This paper is intended to trace a relationship between indentation hardness tests of ductile metals. The most commonly used test has been the Brinell test. But it is known that the hardness number deduced from this test is influenced by the magnitude of the load and the radius of the ball. It does not therefore give a strictly rational measure of hardness. For equal loads the smaller the ball and for equal balls the higher the load, the greater the hardness number. Hence the need of standardising the load and radius of the ball. But as different loads must be used for strong and weak metals, the hardness numbers so obtained are not strictly comparable. Also in comparing Brinell numbers with hardness numbers found by different methods their arbitrary character must be remembered, and an exact agreement is not to be expected.

The variation of the hardness number in the Brinell test with the load and size of ball is at any rate from a scientific point of view a rather serious defect. It arises from the fact that the indentations are geometrically dissimilar.

Dr. Paul Ludwik, of Vienna,† obviated this defect by using for the indenting tool a right-angled cone. The indentations are then always geometrically similar, and the hardness number appears to be to a great extent independent of the load or radius of the indentation. The Ludwik apparatus manufactured in Sweden and Switzerland is now often used especially for the softer metals. But as the results are at present calculated, the hardness numbers differ widely from Brinell's.

Brinell's hardness number is found by dividing the load by the spherical area of the indentation. That is if $P_b$ is the load in kilogrammes, $r$ the radius of the ball, and $a$ the radius of the indentation in millimetres, Brinell's number is $P_b / \{2\pi r (r - \sqrt{r^2 - a^2})\}$. No explanation has been given why the spherical area was taken as the divisor. It is supposed it was to compensate some increase of hardness number when the indentation was deep, probably due to hardening of the metal under the ball as the indentation progressed. But the proper remedy for this is to limit the depth of indentation. Brinell would have been better inspired to have defined the hardness number more simply as :

$$H = P_b / (\pi a_b^2).$$

This will be assumed as a corrected value of Brinell's number. The difference of the two values is not large. For 3,000 kg. and a 10-mm. ball :—

Table I.

| Diameter of Indentation. | Brinell's H. | Corrected H. |
|---|---|---|
| 2·5 | 600 | 612 |
| 4·0 | 228 | 230 |
| 6·0 | 95 | 106 |

In Ludwik's test a right-angled cone is used so that the radius and depth of the indentation are equal. Following Brinell's practice, Ludwik defined the hardness number as the load divided by the conical area of the indentation.

If $P_c$ is the load in kilogrammes, and $a_c$ or $h_c$ the radius or depth of the indentation, Ludwik's hardness number is $P_c / (\pi a_c^2 \sqrt{2})$. But in this paper it is assumed that this also requires similar correction, and the hardness number will be taken to be :

$$L = P_c / (\pi a_c^2).$$

In 1895 and 1900, Lieutenant-Colonel Martel communicated to Paris Congresses on Testing Materials, the results of very interesting researches on indentation hardness. Generally, Martel used an impact method and pyramidal or conical indenting tools, but he also made tests by pressure. The relation between Martel's and Brinell's results has been stated elsewhere.‡ Martel established very conclusively (1) that for a given material the work of indentation is proportional to the volume of indentation and independent (within limits) of the form of the indenting tool. (2) That the pressure causing indentation is at each instant proportional to the area of the indentation normal to the direction of the pressure.

If these laws are accepted as true or approximate, the (corrected) Brinell and Ludwik numbers are the same.

In a ball test, let $P_b$ be the load in kilogrammes, $r$ the radius of the ball, $a_b$ the radius of the indentation, and $h_b$ its depth in millimetres. In a cone test, let $P_c$ be the load, $a_c = h_c$ the radius and depth of the indentation. Since the load is proportional to the area :

$$P_b = k \pi a_b^2.$$
$$P_c = k \pi a_c^2.$$
$$\frac{P_b}{P_c} = \frac{a_b^2}{a_c^2}$$

where $k$ is a constant for a given material. Then the (corrected) hardness numbers are :

$$H = P_b / (\pi a_b^2).$$
$$L = P_c / (\pi a_c^2).$$
$$\frac{L}{H} = \frac{P_c}{P_b} \cdot \frac{\pi a_b^2}{\pi a_c^2} = 1.$$

That is, the Brinell and Ludwik methods give the same hardness numbers.

Table II, below, has been calculated in this way. A series of Brinell values of $a_b$ have been chosen, and the depth and volume of indentation calculated, the load being 3,000 kg., and the ball 10 mm. diameter. For the Ludwik series it has been taken as convenient that the volumes of indentation should be the same, and the corresponding values of $a_c$ and $P_c$ have been calculated.

The volume of a spherical indentation is :

$$V_b = \frac{\pi}{2} a_b^2 h_b$$

$$h_b = r - \sqrt{r^2 - a_b^2},$$

and that of a conical indentation is :

$$V_c = \frac{\pi}{3} a_c^3 = \frac{\pi}{3} h_c^3.*$$

If $V_b = V_c$ :

$$a_c = \sqrt[3]{(\tfrac{3}{2} a_b^2 h_b)}.$$

The agreement of the ball and cone hardness numbers calculated as corrected is evidence that the correction is right. It will be noticed that, for equal volumes of indentation, the load is less and the depth of indentation greater in the cone than in the ball test.

Ludwik prefers to measure the depth instead of the diameter of the impression, and convenient and accurate means of doing this has been devised, for instance by Amsler-Laffon. The depth can be measured during the test and so as to exclude the effect of the extrusion round the indentation, and the subsequent use of a scale and microscope is dispensed with.

Table II.

| Brinell. | | | | Ludwik. | | | | |
|---|---|---|---|---|---|---|---|---|
| Diameter of Indentation. | $a_b$. | $h_b$. | $V_b$. | Load $P_b$ | $a_c = h_c$ | $V_c$. | $P_c$. | H and L. |
| | mm. | mm. | mm. | kg. | mm. | mm. | kg. | |
| 2·5 | 1·25 | 0·16 | 0·3920 | 3,000 | 0·7206 | 0·3920 | 999 | 612 |
| 3·0 | 1·5 | 0·23 | 0·8128 | 3,000 | 0·9189 | 0·8128 | 1,126 | 424 |
| 3·5 | 1·75 | 0·32 | 1·538 | 3,000 | 1·137 | 1·538 | 1,268 | 312 |
| 4·0 | 2·0 | 0·42 | 2·639 | 3,000 | 1·360 | 2·639 | 1,388 | 239 |
| 4·5 | 2·25 | 0·53 | 4·213 | 3,000 | 1·591 | 4·213 | 1,501 | 189 |
| 5·0 | 2·5 | 0·67 | 6·579 | 3,000 | 1·845 | 6·579 | 1,631 | 153 |
| 5·5 | 2·75 | 0·82 | 9·736 | 3,000 | 2·103 | 9·736 | 1,748 | 126 |
| 6·0 | 3·0 | 1·00 | 14·140 | 3,000 | 2·381 | 14·140 | 1,890 | 106 |

It should next be pointed out that there are some secondary causes of difference which may prevent the hardness numbers obtained by different methods being exactly the same. In Martel's impact method there may be an error in determining the work expended due to vibration and rebound. In the Brinell method there is the flattening of the ball and the extrusion at the edge of the indentation. Comparing impact and pressure methods there is a difference due to a time effect. The impact indentation is made in a very short time. In the Brinell method it is prescribed that the pressure should be continued for 2 minutes in the case of a hard metal and 5 minutes in the case of a soft metal. Guillery has shown that the hardness number in a Brinell test is from 8½ per cent. to 14 per cent. greater when the pressure is applied in 2 seconds than when it is applied slowly. Still there is a fundamental identity in all indentation tests.

The Ludwik test seems so rational that the reason why it has not got into wider use is surprising. Probably it is because the point of the cone does not stand the pressure put on it. It is therefore useful to point out that a moderately truncated cone would have nearly the same advantage as a complete cone. Let the cone be right-angled, and $a_1$ the radius of indentation, $a_2$ the radius of truncation, P the load, h the depth of indentation $h = a_1 - a_2$ or $a_1 = h - a_2$. Then the volume of indentation is :

$$V = \frac{\pi}{3} (a_1^3 - a_2^3).$$

The work expended is :

$$T = \frac{\pi}{3} k (a_1^3 - a_2^3).$$

Martell's hardness number is :

$$D = T/V = k.$$

The pressure causing indentation is :

$$P = k \pi a_1^2.$$

And the Ludwik or cone hardness number is :

$$L = P/\pi a_1^2) = k.$$

Although the indentations are not geometrically similar for different loads, they are more nearly so than in the ball test. It may be expected that the hardness number will be within limits independent of the load, and that with moderate truncation the cone will stand up to the pressure.

*Standardisation of Tests.*—Hitherto the ball test has been standardised by fixing standard loads. For the harder metals a load P = 3,000 kg. is used, and for the softer P = 500 kg. and a 10-mm. ball. Now, the secondary causes of variation of hardness number with different indenting methods and different loads diminish as the volume of indentation diminishes. Also it is a question whether in large indentations there is work hardening of the metal as the test proceeds. The rational direction to take in standardising would seem to be to vary the load, so that the volume of indentation is approximately constant.* If the analysis above is correct, it is possible to find beforehand the load required to produce an indentation of approximately a given volume. From experience, $k = H = L$ is known approximately for different materials and for the ball or cone methods.

Suppose that for the ball method the volume of indentation is fixed at 0·81 mm³, corresponding to a radius of indentation, $a = 1{\cdot}5$ mm. Then the load $P = \pi k a^2 = 7{\cdot}07 k$. Similarly for the cone test, let the volume be 2 mm.³, so that the radius of indentation is 1·24 mm. Then $P = 4{\cdot}84 k$.

Table III.

| Material. | $k$ assumed. | Ball Test V=0·81. Load P. | Cone Test. V=2. Load P. |
|---|---|---|---|
| | | kg. | kg. |
| Hard steel .. .. .. | 600 | 4,242 | 2,904 |
| Medium steel .. .. | 400 | 2,828 | 1,936 |
| Mild steel .. .. .. | 200 | 1,414 | 968 |
| Wrought iron .. .. | 100 | 707 | 484 |
| Annealed copper .. .. | 60 | 424 | 290 |
| Lead .. .. .. .. | 8 | 56 | 38 |

The values of $k$ are assumed quite roughly. Any error in assuming $k$ is practically corrected in calculating the hardness number from the observed indentation. The volume of indentation is greater for a less load in the cone test than in the ball test, and this seems an advantage of the cone test. Practically for a moderately truncated cone, the loads may be taken the same as for a cone.

It would seem that the truncated cone test has advantages which it is desirable to investigate, and the ordinary Brinell apparatus can be used.

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Preferential Catalytic Combustion of the Gases of Mixtures.—The belief is still too prevalent that when several gases are mixed with oxygen or air, the hydrogen in the mixture will always burn first, and that there is something like a general sequence of combustibility. In the presence of catalysts at any rate there exists no such general rule, and as it is difficult to keep everything that might act as catalytic agents out of any experimental apparatus, the interpretation of experiments on combustibility is by no means simple. The catalyst may be a metal (platinum, nickel, palladium) spongy or smooth, which adsorbs the one gas more than the other or combines with it; or copper oxide, which gives off its oxygen; an apparently indifferent oxide ($Fe_2O_3$); or porcelain, glass, a firebrick or charcoal, agents which again act mainly through adsorption and occlusion of the gases and which form simply the walls of the furnace or apparatus. Henry observed a hundred years ago that hydrogen and oxygen combine readily in the presence of platinum, which has little effect on mixtures of carbon dioxide, ethylene, or methane with oxygen. Owing to this activating influence of platinum on hydrogen several subsequent experiments, in which platinum tubes were inserted in flames merely to carry off the products of the combustion, were vitiated. In the presence of palladium mixtures of H and O heat up at once and burn, but methane and air are not affected, unless heated to 200 deg. C. Jäger observed that all the hydrogen is burned out of its mixture with methane by copper oxide at 250 deg., when methane is not attacked at all. When Bone and his collaborators in their noteworthy experiments heated various gas mixtures in bulbs of a boro-silicate glass, they found that hardly any reaction set in below 300 deg. C.; then methane was destroyed, much more rapidly than hydrogen was oxidised, and ethane proved more combustible even than methane. Even in bomb experiments with electric-spark ignition, methane appeared much more combustible than hydrogen, and in mixtures of acetylene, hydrogen and oxygen the acetylene was completely oxidised to $CO_2$ whilst the hydrogen remained intact. When such experiments are conducted in large bombs, where the local catalytic effects of the walls would be reduced, the preference of oxygen for methane was still decided, and it therefore seems probable that this preference will continue at high temperature in the absence of any catalysts. On the other hand, the surface combustion of hydrogen is at 500 deg. C., in the presence of firebricks, much more energetic than that of methane. Oxygen absorbed by charcoal, Calvert found, oxidises ethylene readily at ordinary temperatures, but has hardly any effect on hydrogen. Here the catalytic adsorption influence is clear. At very high temperature, Professor Wilder D. Bancroft (Transactions, American Electrochemical Society, vol. xxxii, page 465) concludes—in reviewing these experiments, to which he does not add any of his own—the reactions probably take place so rapidly in the gas phase that the equilibrium reached will be that of the gas phase and not that of the catalytic agent.

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* Paper read before the Institution of Mechanical Engineers, Friday, October 18, 1918.

† "Baumaterialienkunde," xii jahrgang, 1907, page 147. Ludwik, Die Kegelprobe, Berlin, 1908.

‡ Unwin, "The Definition of Hardness," Engineering, May 17 and June 21, 1918.

* According to Ludwik, the volume and hardness number calculated from the radius of the indentation are different from those calculated from the depth, on account of the extrusion of metal round the indentation.

* Martens defined hardness as the load required to force a ball 5 mm. diameter to a depth of 0·05 mm. That is, he fixed on a very small indentation of fixed volume.

# "ENGINEERING" ILLUSTRATED PATENT RECORD.

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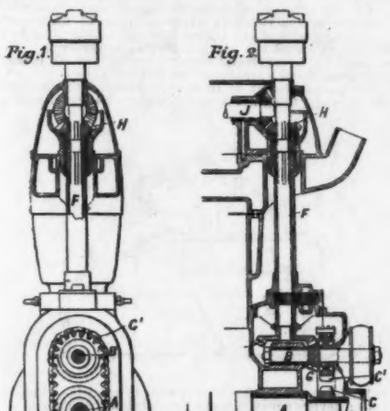
### GAS ENGINES, PRODUCERS, HOLDERS, &c.

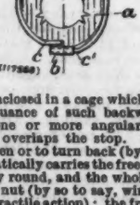
**117,553. Wolseley Motors, Limited, A. A. Remington and E. Reeve, Adderley Park, Birmingham. Internal-Combustion Engine.** (3 *Figs.*) November 5, 1917.—It has been common practice, in the case of internal-combustion engines provided with overhead valves, to operate the valves from an overhead camshaft, driving the camshaft from the crankshaft through the medium of bevel or spiral gears. This invention consist mainly in a combination of chain drive and toothed gear (that is to say, gear in which wheel teeth engage with one another) drive between the crankshaft and the overhead camshaft. According to a convenient method of carrying out the invention, the driving chain wheel C is mounted directly on the crankshaft and the driven chain wheel C1 is mounted upon an auxiliary




shaft B which drives, through the medium of a pair of bevel (or spiral) gears G, a vertical shaft F, and this latter shaft drives the overhead camshaft J through the medium of a second pair of bevel (or spiral) gears H. The intermediate shaft B and the vertical shaft F conveniently afford points for taking drives for the various auxiliaries, and the intermediate shaft, or the camshaft, or both of these, may be extended for the purpose of driving an auxiliary or auxiliaries. The two-to-one ratio between the crankshaft and the camshaft may be introduced at any convenient point. It may, for example, be introduced in the chain-drive or in the lower or in the upper pair of gear wheels. The particular part of the drive where the reduction will be most conveniently effected depends on from what points the auxiliaries are to be driven. (*Sealed.*)

### MACHINE AND OTHER TOOLS, SHAFTING, &c.

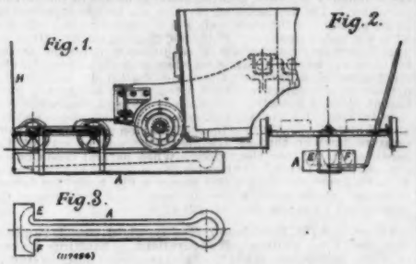
**117,568. W. H. Cook, London, and Fastnut, Limited, London. Nut Locks.** (5 *Figs.*) December 18, 1917.—This invention relates to improvements in washers for locking nuts of the type having means for gripping and engaging the bolt and for holding the nut against vibration by means of a spring member engaging the nut. According to the present invention, the body of the washer *a* is provided with an embracing member of spring metal *e* anchored at one end *e1* and free at the other end, and this free end is adapted to be carried round by the nut during its backward turning and to be jambed against a stop *b* upon the washer so that by the contractile action of the embracing




member *e* the nut is enclosed in a cage which grips and holds the nut against a continuance of such backward rotation. This spring member has one or more angular arms, and its free extremity preferably overlaps the stop. Thus, when the nut commences to unslacken or to turn back (by reason, for example, of vibration) it automatically carries the free end of the embracing member longitudinally round, and the whole member thereupon engages and grips the nut (by so to say, winding or coiling itself on the nut with a contractile action); the free end of the embracing member makes contact with, and is held against, a stop piece and so locks the nut against further backward movement. (*Sealed.*)

### MINING, METALLURGY, AND METAL-WORKING.

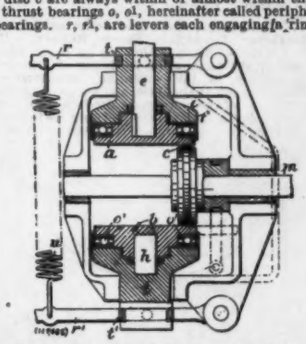
**117,494. The Barrow Hematite Steel Company, Limited, Barrow-in-Furness, and A. M. Butchart, Barrow-in-Furness. A Tilting Tun-Dish.** (3 *Figs.*) July 19, 1917. — This invention consists of a movable tun-dish in connection with what is known as tun-dish casting in the manufacture of steel. It consists of a cast steel trough A lined with refractory materials, the shape and measurement of the said trough varying according to the design of casting ladle and pit with which it is intended to be used. It is usually carried by a separate carriage or bogie; it can be suspended from




the ladle carriage itself if so desired. This tun-dish has two apertures E, F, at the end farthest from the casting ladle, and can be tilted to either side by means of a lever H, and thus the molten metal flowing through it from the casting ladle and into the moulds can be controlled and caused to flow through both or one only of the openings E, F, provided, so that two moulds can be filled simultaneously or one mould alone, or when casting two moulds, if one is filling faster than the other, the flow of metal can be regulated to finish both at the same moment. (*Sealed.*)

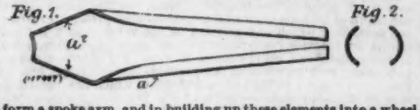
### MOTOR ROAD VEHICLES.

**117,465. H. Biggleston, Canterbury. Variable-Speed Gears.** (10 *Figs.*) January 13, 1917.—This invention has reference to variable speed gears of the type wherein a pair of coaxial discs make frictional contact with opposite parts of the periphery of an intermediate disc mounted at right angles to them on a shaft, the axis of which cuts their common axis and along which shaft the intermediate disc is movable towards and from the common axis of the pair of discs, and wherein the pair of discs are forced towards each other by spring pressure in such a manner as to exert equal pressure on the intermediate disc in opposite directions. According to this invention, the pair of opposed discs *a*, *b*, are supported at their outer side by ball thrust bearings *o*, *o1*, arranged near to their outer peripheries so that the points of contact of the opposed discs with the intermediate disc *c* are always within or almost within the area of the ball thrust bearings *o*, *o1*, hereinafter called peripheral ball-thrust bearings. *r*, *r1*, are levers each engaging a ring *f* or *f1*,




encircling the grooved outer end of the bearing *f* or *f1*, the other ends of the two levers being connected together by a coiled tension spring *u*. By the arrangement described, the two discs *a* and *b* will be forced by the bearings *f* and *f1* equally against opposite parts of the periphery of the intermediate disc *c* by the action of the spring *u* acting through the levers *r* and *r1*, bearings *f* and *f1* and sets of anti-friction balls *e* and *e1*, so that when the disc *a* is rotated by its shaft *a'*, the disc *c* and the driven shaft *m* will be rotated by the disc *a* at a speed which can be varied at will by moving the intermediate disc *c* along the said shaft and across the faces of the discs *a* and *b*, the latter disc acting as a support only. Also, it will be seen that notwithstanding very great pressure may be exerted between the discs, when the intermediate disc *c* is near to the outer peripheral portions of the discs *a* and *b*, the latter will be rigidly supported in position by the ball-thrust bearings *o* and *o1*, and prevented from bending or canting about the shafts *c* and *h* as fulcrums. (*Sealed.*)

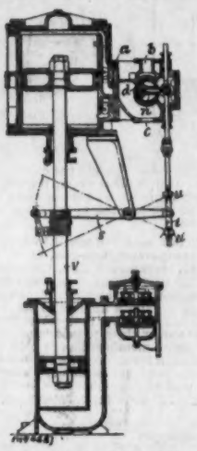
**117,467. J. S. Foley, Stourbridge, and F. W. Baker, Stourbridge. Wheels.** (8 *Figs.*) February 22, 1917.—This invention has reference to motor-vehicle wheels of the type that embody spokes which are produced from wrought or sheet metal and are secured to the hub and felloe by mechanical means. The present invention consists in producing the spoke elements of a wheel from strip metal by making each such element complete from one length of strip *a*, the middle portion of which is fashioned into a wedge-shaped nave or hub end *a2*, whilst the remaining portions of the said strip are so disposed that they together




form a spoke arm, and in building up these elements into a wheel, they are disposed so that the greatest width of the strip metal section lies across or at right angles to the plane of the wheel and their connection to the hub or centre and felloe is effected by mechanical devices preferably whereby the said elements are subjected to and maintained under longitudinal tension. According to one form of this invention, the wheel embodies a series or system of separate spokes or spoke elements which are each produced or fashioned individually from a length of strip metal, and which have a shape or formation substantially as shown in the drawing. (*Accepted July 31, 1918.*)

### PUMPS.

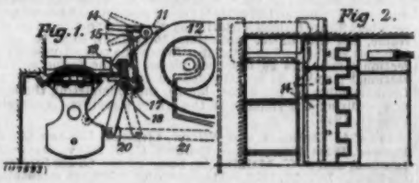
**117,468. James Simpson and Co., Limited, London, and J. Marsland, New Balderton. Pumping Engines.** (5 *Figs.*) April 11, 1917.—This invention relates to piston valves for pumps of the type in which the valve located within a liner within the valve chest has imparted to it an axial movement by the motive fluid to be controlled and an oscillatory movement by means of a mechanical connection operated by a moving part of the pump or other device to the control of which the valve is applied. The invention consists in a valve of the above character comprising a valve chest *a* with the necessary motive fluid inlet and exhaust openings *b*, *c*, therein, a liner *d* within




the valve chest having port openings therein, and a quadrant-shaped valve *n* within the liner adapted to control the said port openings and subject to fluid pressure on the side remote from said openings. For the purpose of imparting rotary or oscillatory motion to the valve, the usual lever *s*, link *t*, and adjustable tappet *u* connections are provided between the pump piston rod *v* and the valve in order that the oscillatory movement of the valve may synchronise with the strokes of the piston in the steam cylinder of the pump. The operation of the valve is substantially similar to that of the known construction of valve of the type to which the invention relates. (*Sealed.*)

### [STEAM ENGINES, BOILERS, EVAPORATORS, &c.

**117,593. Babcock and Wilcox, Limited, London, A. E. Parker, West Hampstead, London, C. S. Davy, Dulwich, London, and D. G. Meiklereid, Lee. Chain-Grate Stokers.** (3 *Figs.*) June 19, 1917.—This invention relates to the ash plates of mechanical chain-grate stokers. In accordance with this invention, the ash plate comprises a forwardly-projecting portion to contact with the rear end of the stoker and a rearwardly projecting portion or portions hinged thereto and adapted to be raised or lowered independently of the forwardly-projecting portion, so as to form a variable resistance to the clinker passing over into the ash pit of the stoker and to allow large clinkers to be deposited rapidly into the ash-pit. The ash-plate is in two parts, the main portion 11 resting on the rear end 12 of the grate and forming an air seal, ample movement being allowed to the




nose to follow the movement of the grate. To the portion 11 is hinged a rearwardly-extending flap or flaps 14, which flap forms a variable resistance to the clinker as it can be moved into any desired position to suit various classes of coal without interference with the continuous operation of the stoker. One form of such mechanism consists of a lifting rod or rods 15 for supporting the flap 14 passing through a guide or guides formed in the body of the ash plate and operated by one or more levers 17 to which the lifting rods 15 are attached, said levers 17 being mounted on a shaft 18 below the bearers 19, and arranged to slide along the shaft 18 to any desired position central with the guide formed in the body of the ash plate. The operating lever or levers 17 can be manipulated either at the rear or through the side wall or from the front of the stoker by means of levers 20 and connecting rods 21. (*Accepted July 31, 1918.*)

**117,475. The Hon. Sir C. A. Parsons, Newcastle-on-Tyne, S. S. Cook and L. M. Douglas, Wallsend-on-Tyne. Packing.** (6 *Figs.*) June 19, 1917.—The present invention relates to glands for packing rotating shafts. The invention consists in a gland for packing rotating shafts having two or more spring-pressed segmental packing rings of carbon in each groove, one of the rings having the usual open joints, while another has closed joints held closely together by means of the spring. The gland *a* is provided with three grooves *b*, *b*, *b*, each groove being slightly wider than the width required for the two carbon packing rings *c*, *d*. A fairly large clearance is left between the shaft *e* and the inwardly-projecting metallic flanges *f*, *f*, on the gland *a*. The carbon ring *c* on the steam side in each groove has the usual open joints *g* and is pressed on the shaft by the spring *k*, while the segments of the other carbon ring *d* in each groove have closed joints *h*, the ends of the segments being held close against each other by means of the spring *l*. There may be a clearance between the bore of the second rings *d* and the shaft, but this clearance can be made exceedingly small, preferably just sufficient to ensure that the joints between the segments are closed. The two rings *c*, *d*, are arranged so that their joints *g*, *h*, are not opposite each other, so that the second rings almost completely cover the open joints of the rings on the steam side, so that leakage is reduced to a very small amount. Stops are usually provided to prevent the carbon rings from rotating with the shafts, and in the case of the ring *c* with the open joints

this stop *m* is preferably provided at the top of the gland. The effect of this is that with either direction of rotation of the shaft, on account of the friction between the carbon segments and the shaft, the accumulated opening of all the joints occurs at the

Fig. 1.

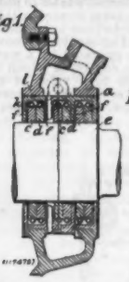
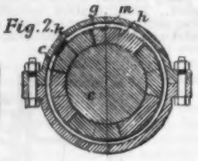


Fig. 2.



top, adjacent to the stop. Should the closed joint ring be large in the bore due to wear or other cause, its weight will cause it to ride upon the shaft at the top, and the opening of the joints of the other ring being also on top, this opening will be most effectively blanked. (*Sealed.*)

**117,894. Babcock and Wilcox, Limited, London, A. E. Parker, West Hampstead, London, C. S. Davy, Dulwich, London, and D. G. Meiklereid, Lee. Chain-Grate Furnaces.** (5 *Figs.*) June 19, 1917.—This invention relates to ash doors. Each door is composed of two castings 26, one at each end united by frame members 27, and a number of sectional members 29, the sectional members being preferably formed with offset projections so as to allow them to interlap. In the form shown in Fig. 1, the sectional members 29 are held in position by set screws passing through plates on the under side of the frame and engaging lugs on the sectional members, while in the form shown Figs. 2 to 5, the sectional members are formed with inwardly-projecting lips 32. In the latter construction, the door is com-

Fig. 1.

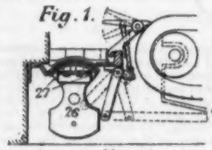


Fig. 5

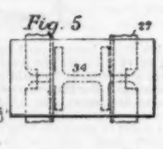


Fig. 2.

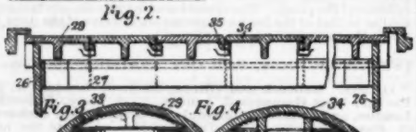
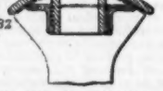


Fig. 3.

Fig. 4.



posed of two castings 26, one at each end, united by suitable frame members 27 and a number of sectional members 29. The top flange of each member 27 is recessed at one point to allow, the passage of the inwardly-projecting lips and receive the sectional members 29, which are dropped into place on the frame and moved right and left to their proper positions. The sectional members 29 are formed with ribs 33 which support them on the frame, and with off-set projections 35 (Fig. 2), so as to allow adjacent sections 29 to interlap. When the correct number of sectional members 29 has been placed on the frame a final sectional member 34 is introduced and bolted securely to the frame member by bolts (not shown), thus completing the door and ensuring the rigidity of the whole structure. (*Accepted July* 31, 1918.)

**117,476. Babcock and Wilcox, Limited, London, A. E. Parker, West Hampstead, London, C. S. Davy, Dulwich, London, and D. G. Meiklereid, Lee. Chain-Grate Stokers.** (4 *Figs.*) June 19, 1917.—This invention relates to mechanical chain-grate stokers. A feature of the invention consists in an arrangement in the stoker, of fixed division plates and movable

Fig. 1.

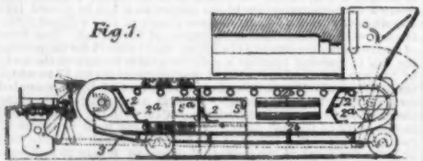
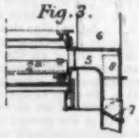


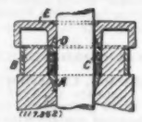
Fig. 2.

Fig. 3.



division plates hinged thereto in conjunction with movable division plates in the form of louvres in the side walls of the stoker, whereby such stoker can be used under conditions of natural draught, or alternatively, and without any interference with the working of the stoker, with air under pressure. The chain-grate stoker is fitted with a series of fixed division plates 2 to which are hinged movable plates 2*a* which, while permitting of free movement of the chain forming the grate, prevent any material discharge of air from one division to another. In conjunction with these fixed and movable plates are provided a series of movable plates 2*b* in the form of louvres arranged in the side wall of the grate, which louvres can be opened to allow air to flow into the space between adjacent sets of division plates 2, 2*a*. The stoker carriage 3 is formed with an aperture 4 designed to receive and make contact with an air duct 5 in the wall 6 of the furnace in such manner as not to interfere with the free withdrawal of the stoker from the furnace, the connections being so arranged that when the stoker is in its proper position in the furnace the openings through the carriage frames are completely shrouded and the material escape of the air thus prevented. The air duct 5 serves *inter alia* for the supply of air under pressure to the stoker when it is desired to burn the fuel with air under pressure. A hinged plate 7, fitted in the air duct 5, permits air under natural conditions to enter the interior of the stoker by way of said duct when desired, said plate 7 also functioning as a damper to shut off the supply of air under pressure. Air-control valves 8 fitted in the air duct 5 serve to control the air pressure when desired. When air under pressure is to be used with the stoker, the louvres 2*b* are closed and the hinged plate 7 brought into upright position when the air under pressure flows up through the air duct 5 and by way of the openings 5*a*, 5*b*, into the stoker. When natural conditions of draught are to be used, the louvres 2*b* are opened and the hinged plate 7 lowered into the position shown in Fig. 3, air then flowing from the outside through the air duct 5 and also through the ouvres 2*b*. (*Accepted July* 31, 1918.)

**117,352. L. H. Hopkinson, Huddersfield, and J. Hopkinson and Co., Limited, Huddersfield. Stuffing Boxes.** (1 *Fig.*) September 27, 1917.—This invention relates to stuffing boxes and provides an improved method of packing the same. According to the present invention, there is combined with a conical bush and loose or yielding packing in the stuffing-box, a second conical bush, situated in the gland, and having its large end bearing on the loose packing in the box. A is a conical bush seated in the conical end of the stuffing-box B, and C denotes



loose packing bearing on the base of the conical bush A. In combination with this bush and loose packing there is employed another conical bush D, situated in a conical recess on the gland E and so arranged that the large end or base of the bush D bears on the loose packing C. This conical bush is made of soft metal and serves to form a joint or packing in the gland which supplements that made by the conical bush A and loose packing C in the stuffing-box, and thus enables a tighter packing to be obtained without unduly pressing on the spindle or rod F. Each conical bush may be made in one piece, or it may be made, if desired, in sections. (*Sealed.*)

**117,011. Ransomes, Sims and Jefferies, Limited, and A. P. Keightley, Ipswich. Steam Boilers.** (7 *Figs.*) November 1, 1917.—This invention related to the construction of the roofs of the rectangular fire-boxes of locomotive-type boilers. According to this invention, two crescent-shaped corrugations are made at the sides, and not passing through the centre, o the roof of the rectangular fire-box, with their points extending towards the angles of the roof, and are joined together by a corrugation passing through the centre of the roof. In

Fig. 1.

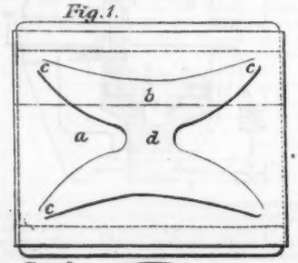


Fig. 2.

some cases the two corrugations may consist of two parallel corrugations at the sides of the roof and joined together by another passing through the centre of the roof, thus forming corrugations in the shape of an H. *a* is the roof of the fire-box having in it crescent-shaped corrugations *b*, *b*, with their points *c*, *c*, *c*, *c*, extending towards the angles of the roof. The crescent-shaped corrugations *b* are joined together by a corrugation *d* passing through the centre of the roof. (*Sealed.*)

**116,967. Cockburns, Limited, D. Cockburn and D. MacNicoll, Cardonald, near Glasgow. Valves.** (3 *Figs.*) August 17, 1917.—This invention relates to a valve device for controlling the passage of fluid under pressure simultaneously to two turbine stages, said device being adapted to permit the passage of fluid to said stages only when the turbine groups to which said stages belong are both running ahead or both running astern. 1 denotes the turbine exhaust control valve proper, the required movement of which is effected by pressure of steam, the passage of which to a piston 2 on the valve stem 3 is determined by a device comprising aligned movable valve members 4, 5, the member 4 being subject to steam which has passed the port ahead turbine valve of the previous turbine stage, and the member 5 subject to the pressure of steam which has passed the starboard ahead turbine valve of the previous turbine stage, said members 4, 5, being fitted within a casing 6 in end-to-end abutting relationship so as to be incapable of being both seated simultaneously, but each adapted, when seated, to cut off flow of steam from the corresponding ahead turbine valve to a port 7 in the casing leading to the piston 2. For example, assume that the port ahead turbine valve is open; in that event the steam acting on the member 4 will urge the latter towards its seat. If the starboard ahead turbine valve be closed, the member 4 will encounter no resistance in displacing the member 5 away from its seat. The conditions being as stated, no steam will pass to the port 7. If, however, the starboard ahead turbine valve be open, the steam passes the member 5 through the port 7 to the piston 2, the position of the members 4, 5, being then dependent on the difference of pressures of steam supplied from

Fig. 1.

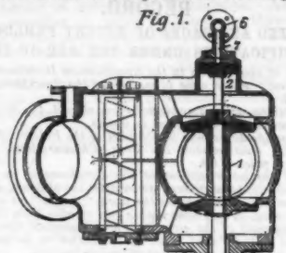
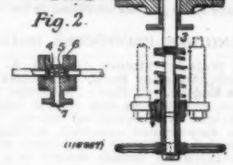
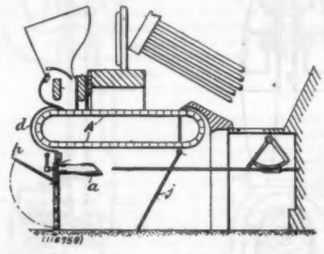


Fig. 2.



the ahead turbine valves. If the pressures be equal, the members 4, 5, may be in any position, the members 4, 5, taking up their position at the moment of neutralisation of the operating force which occurs on the equalisation of the pressures. (*Sealed.*)

**116,750. S. J. Ross and H. Schofield, London. Steam Boilers.** (3 *Figs.*) June 16, 1917.—This invention has reference to forced-draught arrangements for steam boilers, and relates to means for applying a forced draught to boilers having travelling or revolving grates of the endless-belt type. According to the invention, the front end of the travelling or revolving grate A is enclosed by a sheet-metal casing *d* having beneath it one or more flaps or doors *h* for closing the front of the ash pit and an air-blower arrangement or injector system is provided which forces air under the grate A through suitable injector nozzles *a*



or induction pipes by means of steam or air jets. Such air-induction devices *a* may be immediately below the front end of the grate, and beneath them may be arranged the door or doors *h* to close in the front of the ash pit. At the rear of the grate a hinged metal plate or flap *j* may be arranged to deflect the blast at the back of the ash pit upwardly towards the gate. In some cases, however, where the grate is mounted between side plates or frames, the air-induction devices or injectors may be fitted in apertures in such side plates and be arranged to project a stream of air below the fire horizontally and transversely or otherwise as desired. (*Sealed.*)

## MISCELLANEOUS.

**116,803. W. H. Haywood, Huddersfield. Glazing Bars.** (3 *Figs.*) August 15, 1917.—This invention relates to puttyless glazing bars. *a*, *b*, represent two longitudinal bars of which the bar *a* forms the cap or astragal above the adjacent edges of the sheets of glass *c*, and the bar *b* forms a trough below said sheets of glass, the bars *a*, *b*, being secured by stud bolts *d* to, and supported by, a longitudinal bar *e* of T-shape in cross-section. The astragal *a* is, preferably, rounded or of arch shape in cross-

section, and is provided with longitudinal grooves *a*1 to give a grip upon a strip of bitumen treated asbestos interposed between said astragal and the upper faces of the opposing sides of the sheets of glass *c* to make a weathertight joint when the cap is secured firmly in position. The bar *b* is provided near each longitudinal edge with half-circular grooves *b*2 to receive packings *g* to make weathertight joints between the under surfaces of the sheets of glass *c* and the bar *b*. (*Accepted July* 3, 1918.)

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**Shipbuilding in Germany.**—The Blohm and Voss shipyard in Hamburg has for the last financial year earned a surplus of 11,018,581 marks, against 8,388,646 marks for the previous year. Expenditure for war aid absorbed 2,146,445 marks, against 1,782,377 marks in the previous year and writings-off rose from 3,220,291 marks to 4,885,888 marks. The net profits amounted to 2,747,385 marks, against 2,376,983 marks for the preceding year. The preference shares receive 5½ per cent., and the ordinary shareholders 7 per cent., against 6 per cent. the previous year. Ships and ships' parts in course of construction figured in the balance sheet for 111,000,000 marks, against 82,800,000 marks at the end of the preceding year. The holding of stocks and bonds had risen from 6,900,000 marks to 10,500,000 marks.